(12) UK Patent Application (19) GB (11) 2 007 162 A

(21) Application No 7838899
(22) Date of filing 2 Oct 1978
(23) Claims filed 2 Oct 1978
(30) Priority data
(31) 52/118798
(32) 3 Oct 1977
(31) 52/125406
(32) 19 Oct 1977
(31) 53/101189
(32) 18 Aug 1978
(31) 53/101188
(32) 18 Aug 1978
(33) Japan (JP)
(43) Application published
16 May 1979
(51) INT CL^2
B41J 3/04
(52) Domestic classification
B6F LQ
F1R 3A3C
(56) Documents cited
None
(58) Field of search
F1R
(71) Applicants
Canon Kabushiki Kaisha,
30-2, 3-chome,
Shimomaruko, Ohta-ku,
Tokyo, Japan
(72) Inventors
Ichiro Endo,
Yasushi Sato,
Seiji Saito,
Takashi Nakagiri,
Shigeru Ohno
(74) Agents
R. G. C. Jenkins & Co

(54) Liquid Jet Recording Process and Apparatus Therefor

(57) Liquid droplets are formed by instantaneous state change by applying thermal energy to a liquid (ink) in a chamber to cause a volumatic change in the liquid and thus the expulsion of liquid from the chamber towards a recording medium. The thermal energy may be generated by a electrothermal or photothermal transducer.

GB 2 007 162 A

FIG. 1

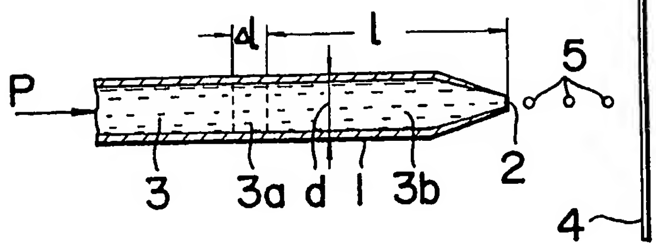


FIG. 2

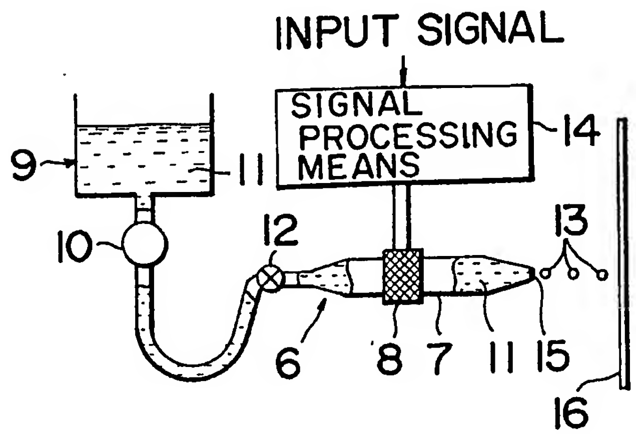


FIG. 3

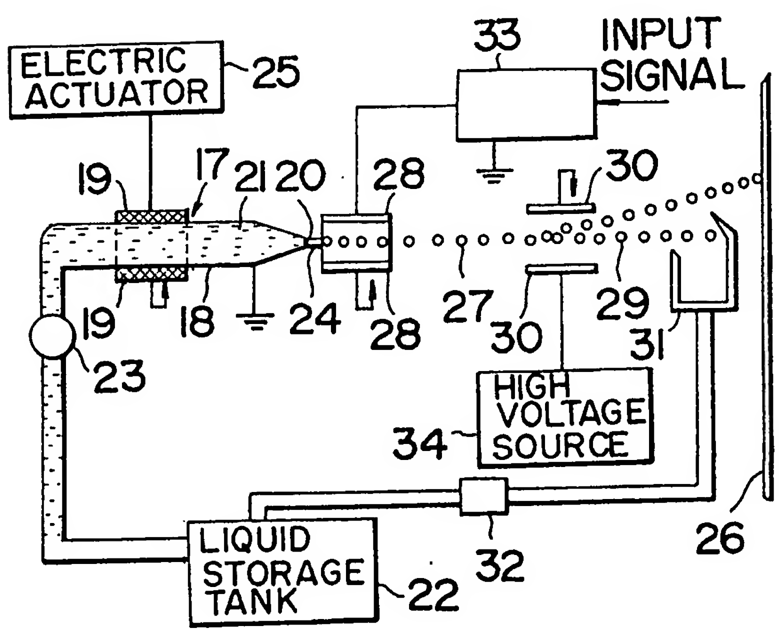
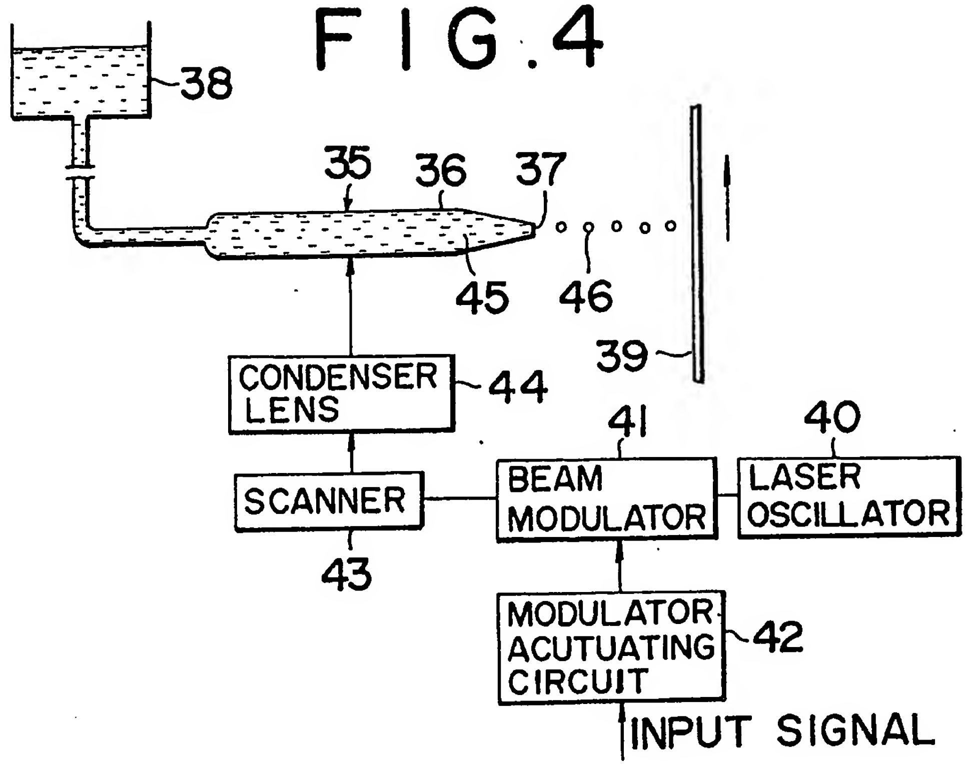
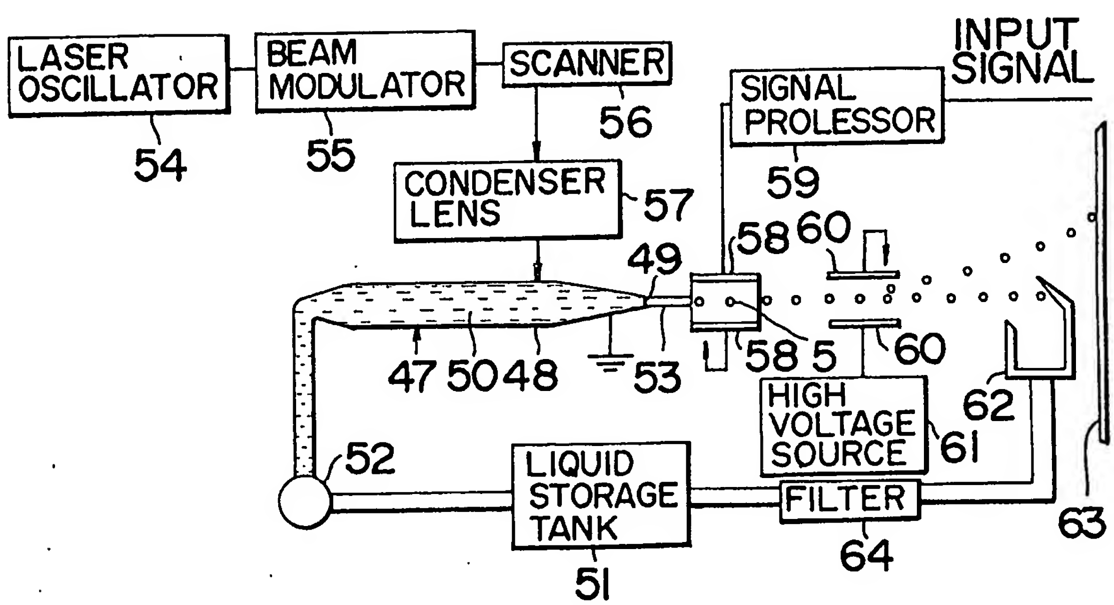


FIG.4

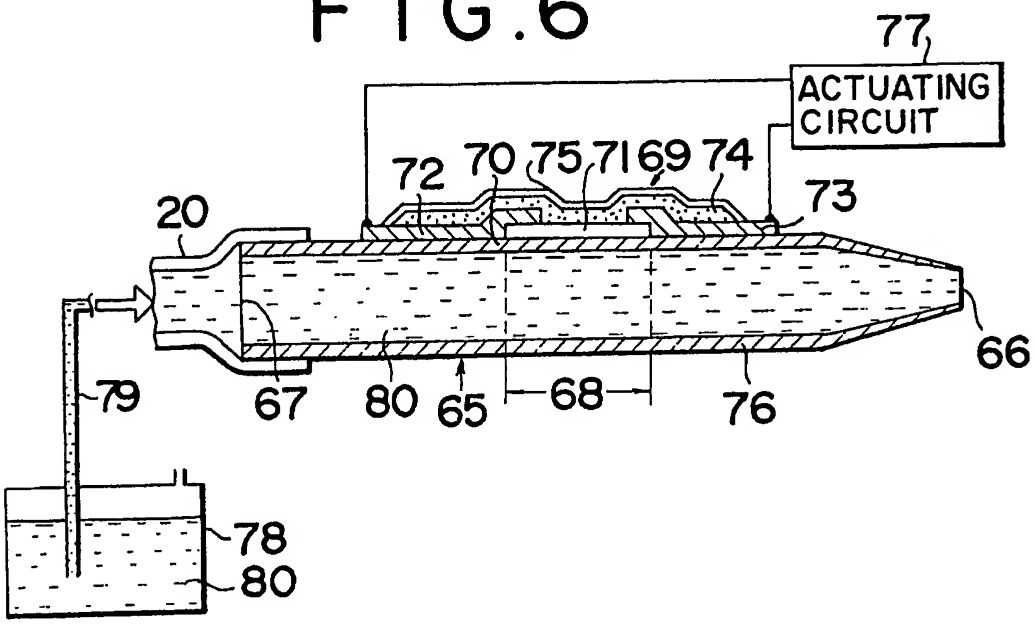


38
35
36
37
45
46
39
CONDENSER LENS
44
41
40
SCANNER
BEAM MODULATOR
LASER OSCILLATOR
43
MODULATOR ACUTUATING CIRCUIT
42
INPUT SIGNAL

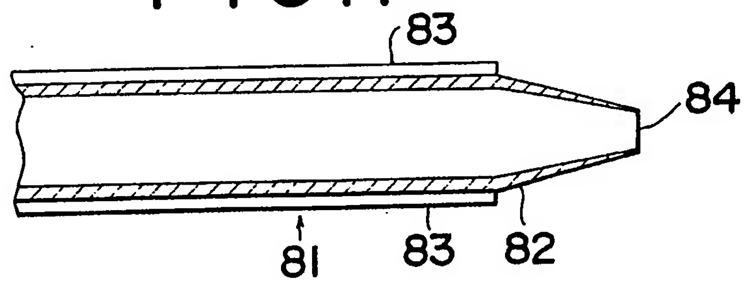
FIG.5



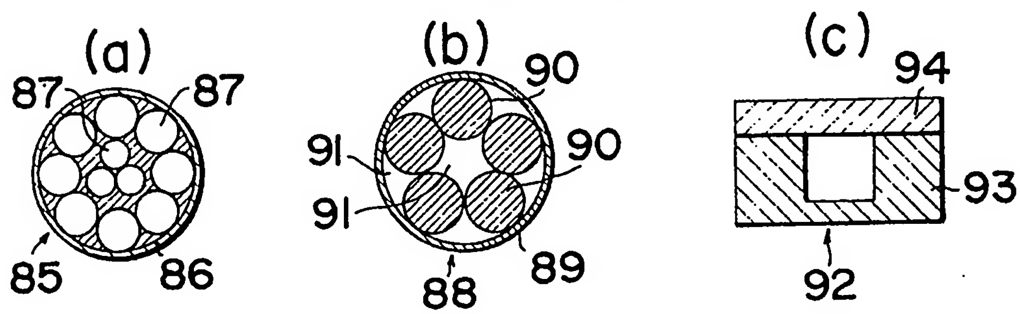
LASER OSCILLATOR
BEAM MODULATOR
SCANNER
INPUT SIGNAL
SIGNAL PROLESSOR
54
55
56
CONDENSER LENS
57
59
58
60
49
47
50
48
53
58
5
60
HIGH VOLTAGE SOURCE
61
62
52
LIQUID STORAGE TANK
FILTER
63
64
51



F I G.6



F I G.7



F I G.8

FIG.9a

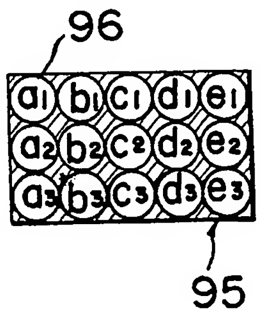


FIG.9b

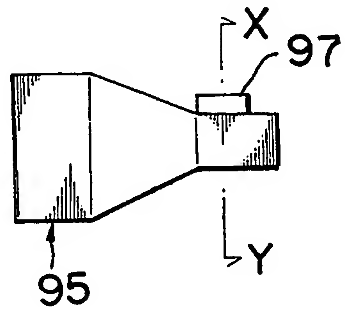


FIG.9c

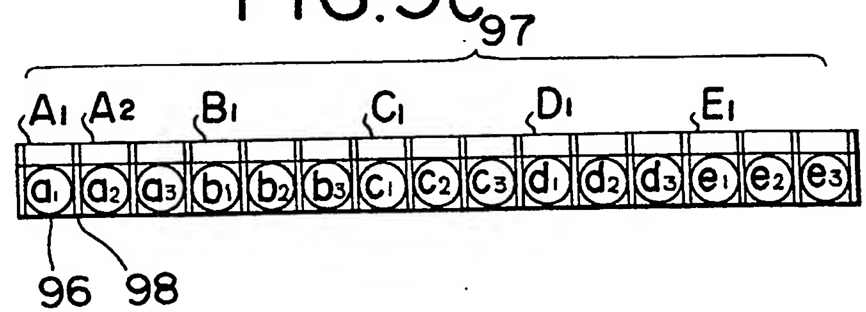


FIG.10a

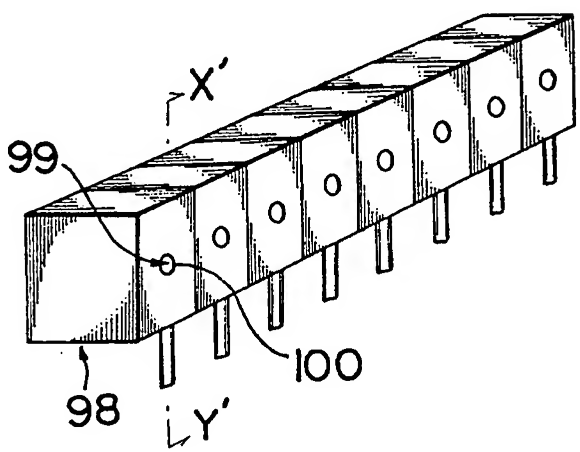


FIG.10b

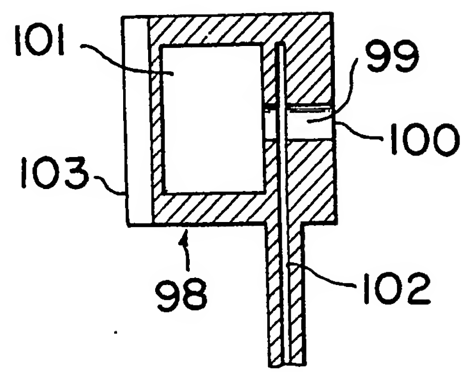


FIG. 11

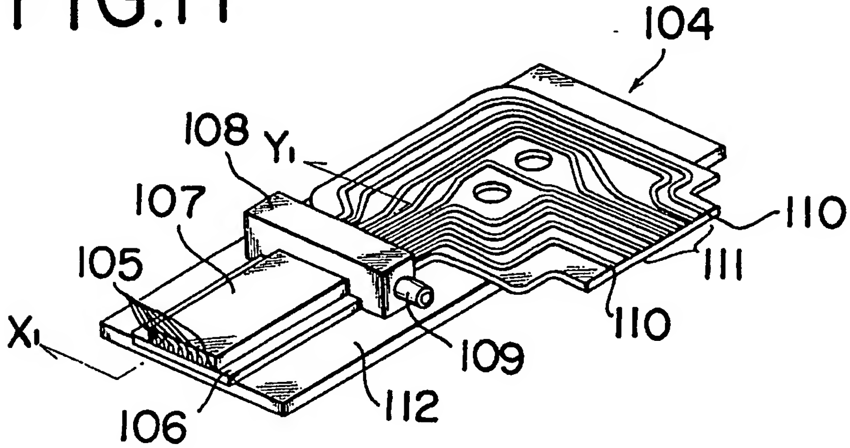


FIG. 12

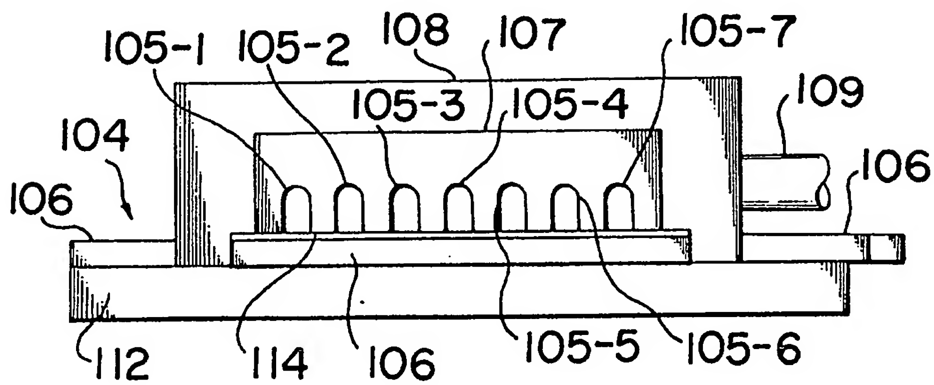


FIG. 13

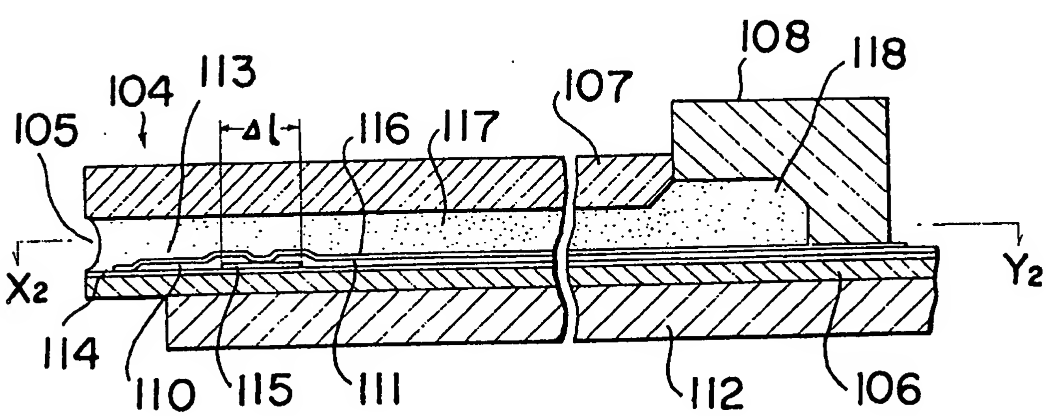


FIG.14

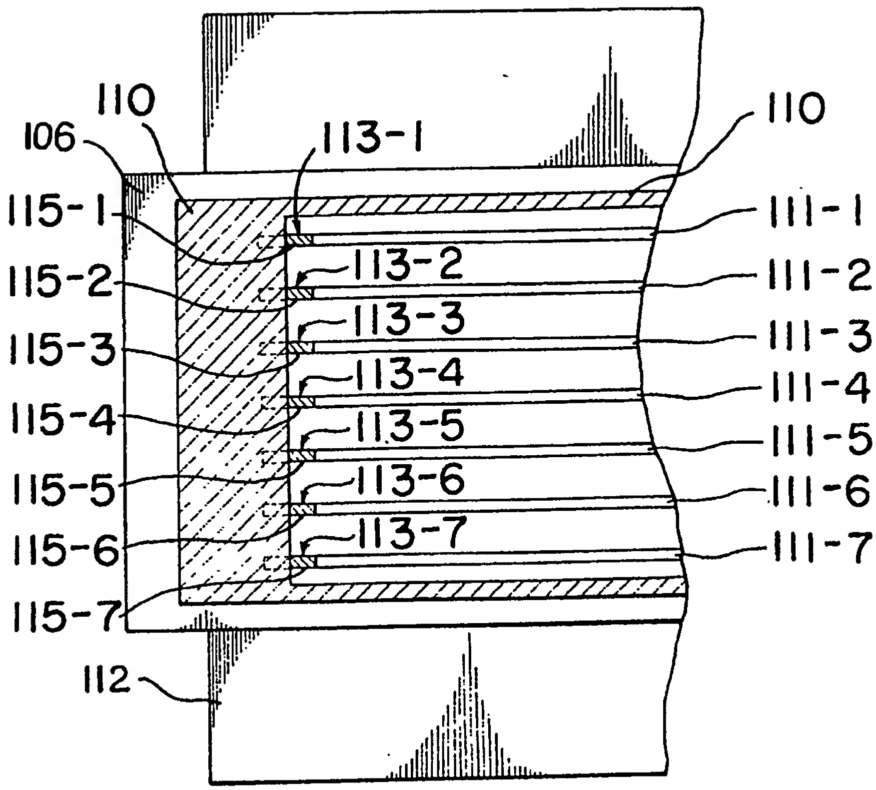


FIG.15

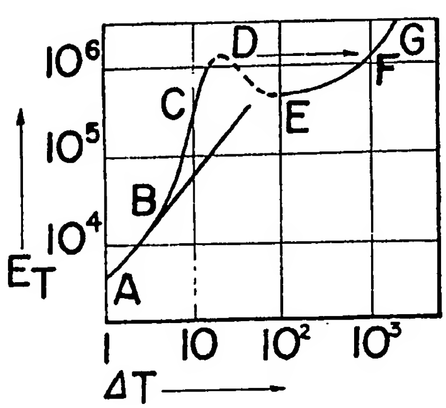
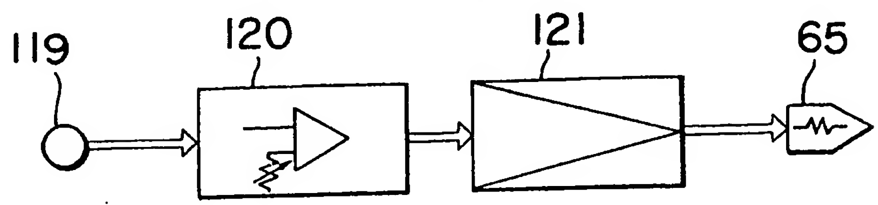


FIG.16



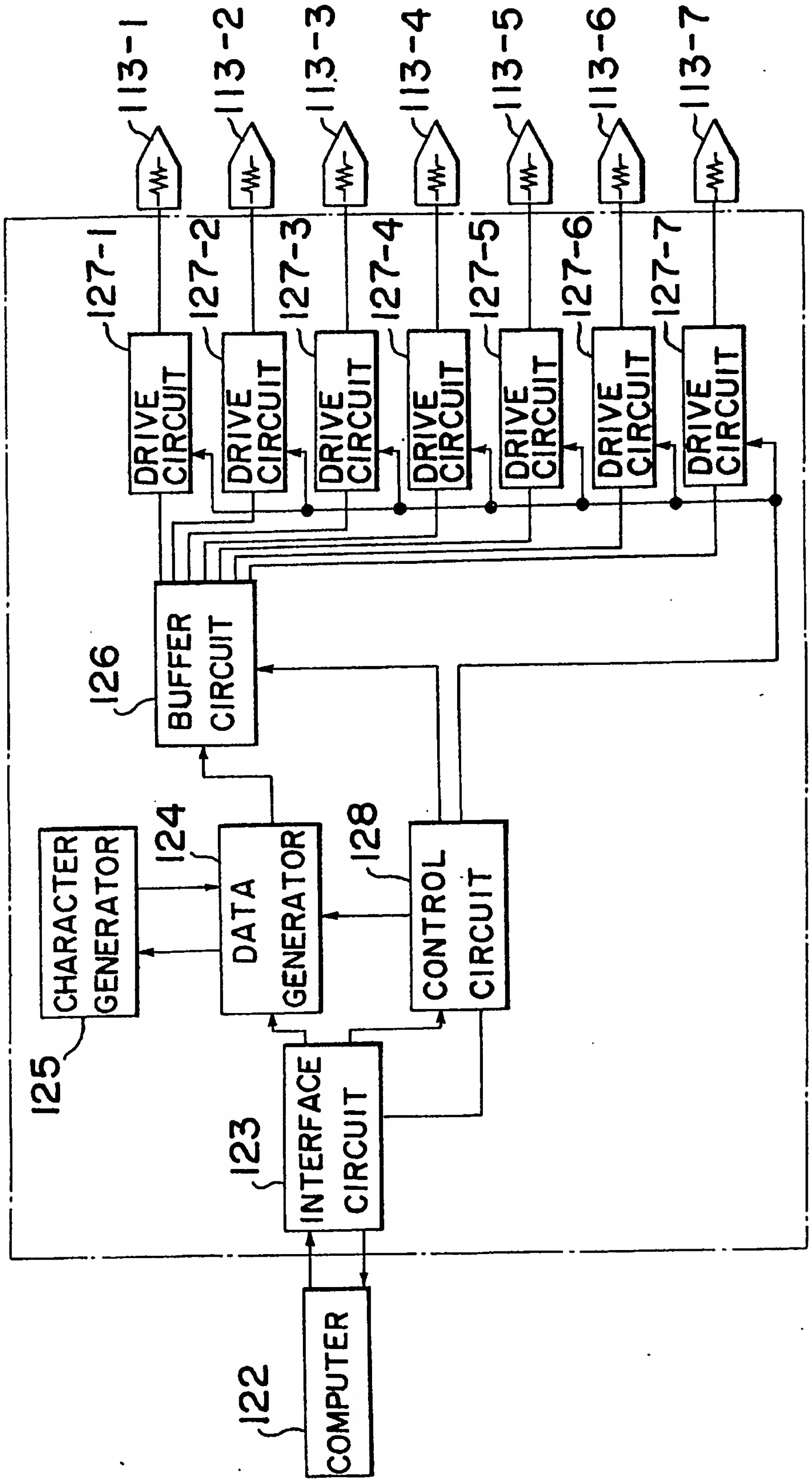

113-1
113-2
113-3
113-4
113-5
113-6
113-7
127-1
127-2
127-3
127-4
127-5
127-6
127-7
DRIVE CIRCUIT
DRIVE CIRCUIT
DRIVE CIRCUIT
DRIVE CIRCUIT
DRIVE CIRCUIT
DRIVE CIRCUIT
DRIVE CIRCUIT
126
BUFFER CIRCUIT
124
DATA GENERATOR
CHARACTER GENERATOR
125
128
CONTROL CIRCUIT
123
INTERFACE CIRCUIT
122
COMPUTER

FIG.17

2007162

FIG.18

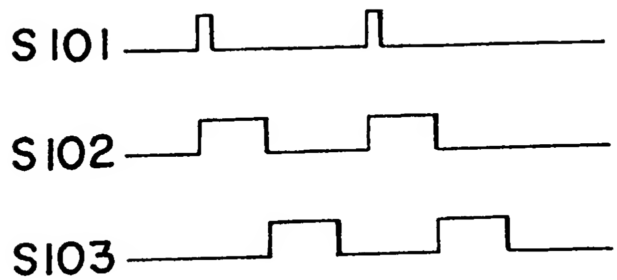


FIG.19

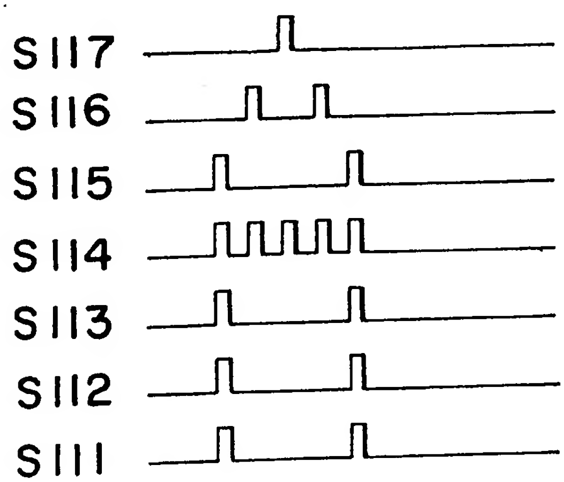


FIG.20

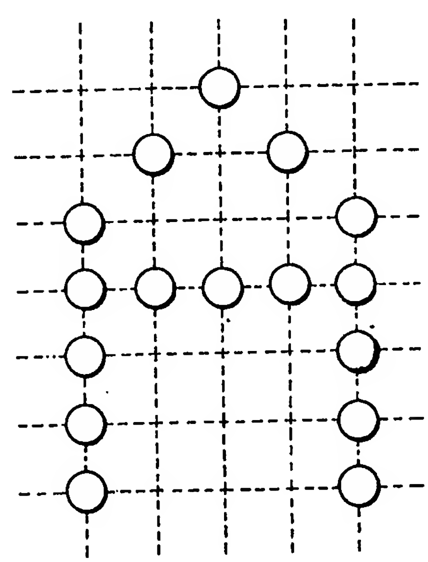


FIG.21

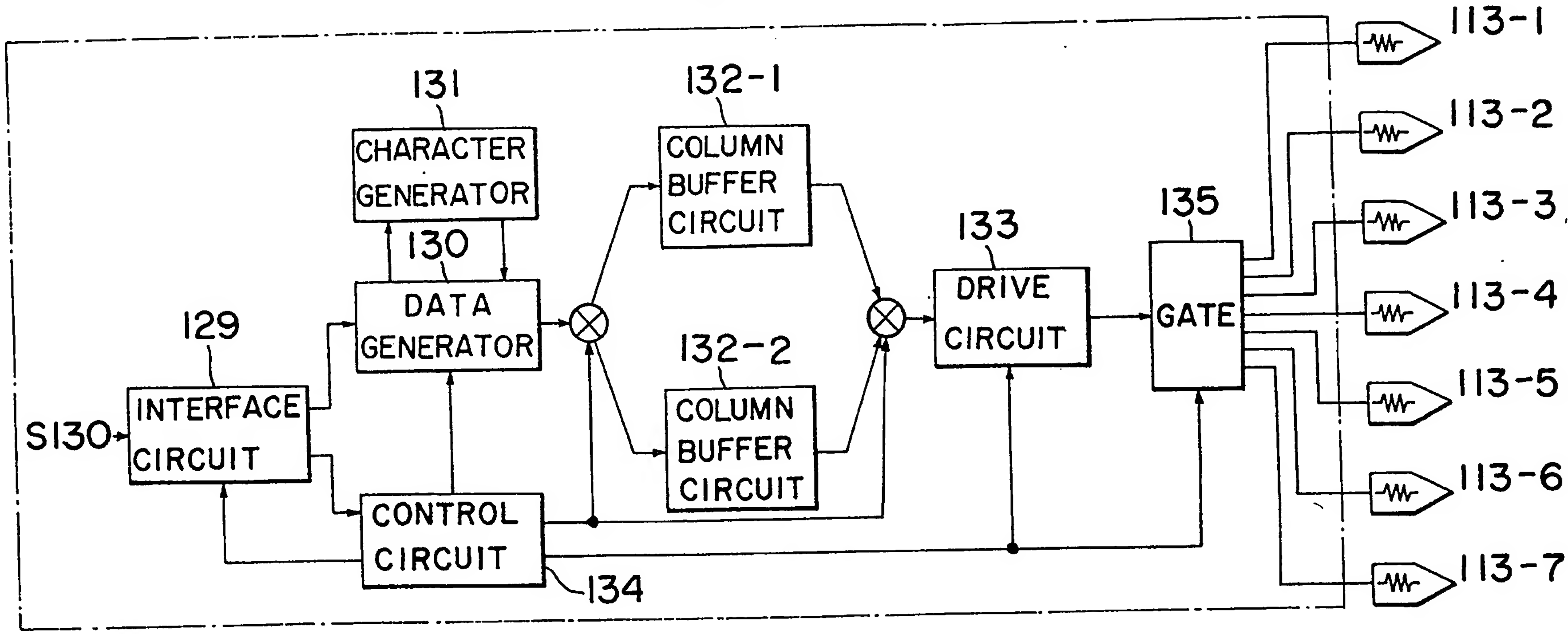
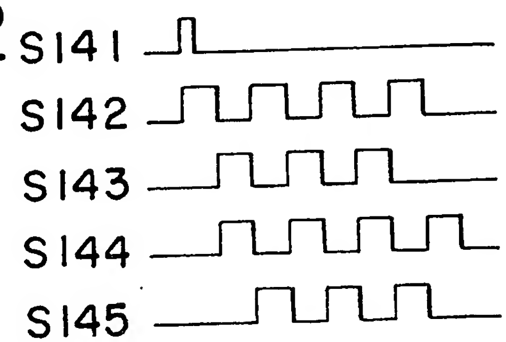


FIG.22



2307162

2307132

FIG.23

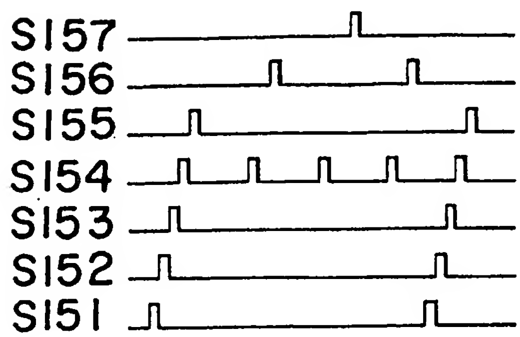


FIG.24

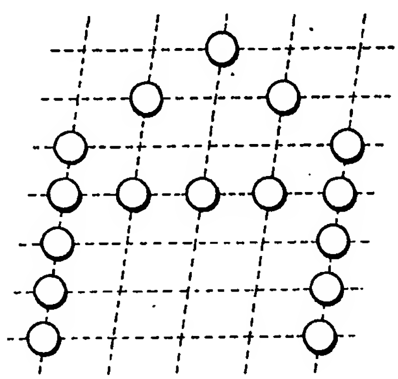


FIG.25

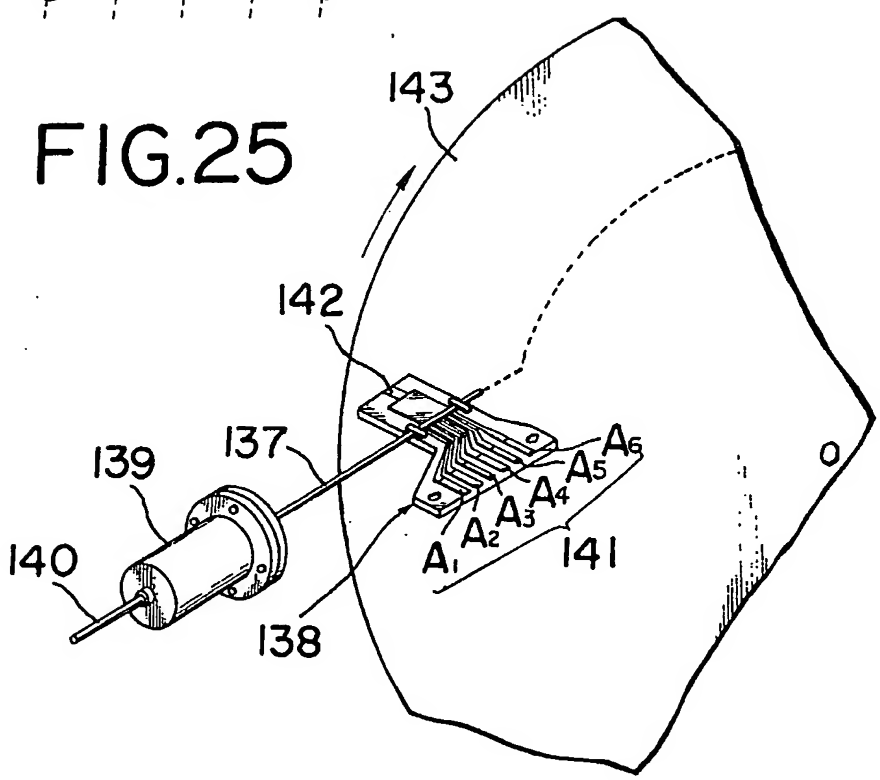


FIG.26

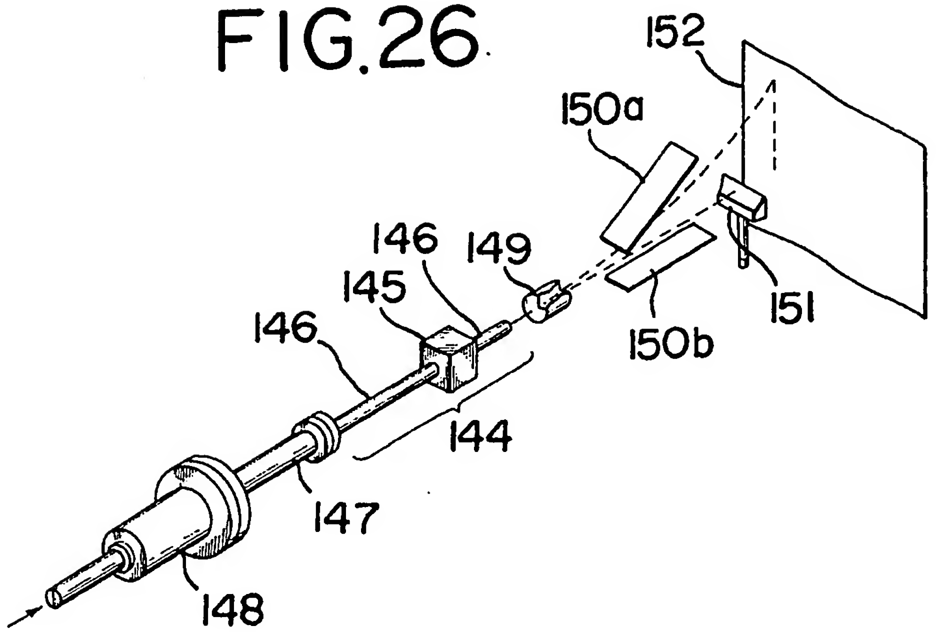

152
150a
146
149
145
146
151
150b
144
147
148

FIG.27

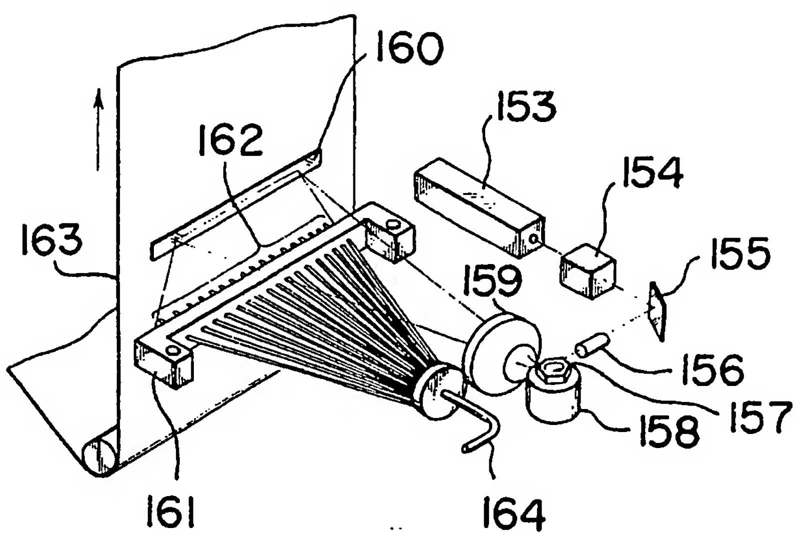

160
153
162
154
163
155
159
156
157
158
161
164

FIG.28

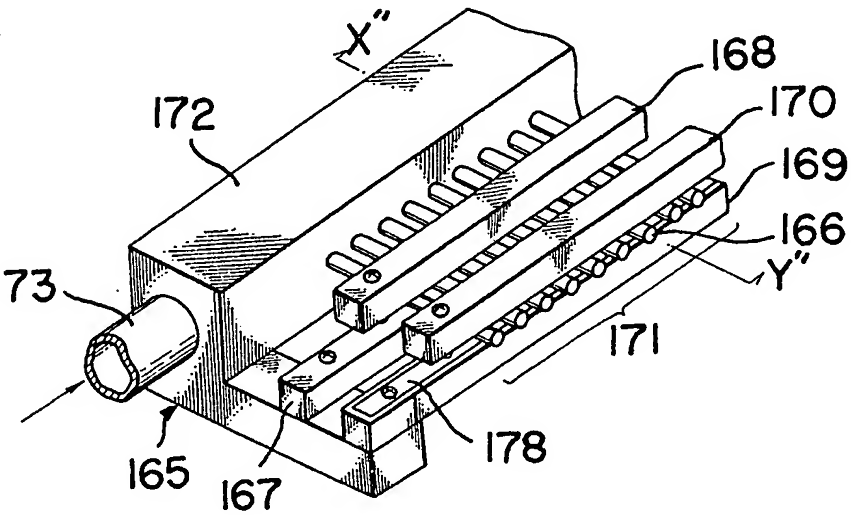
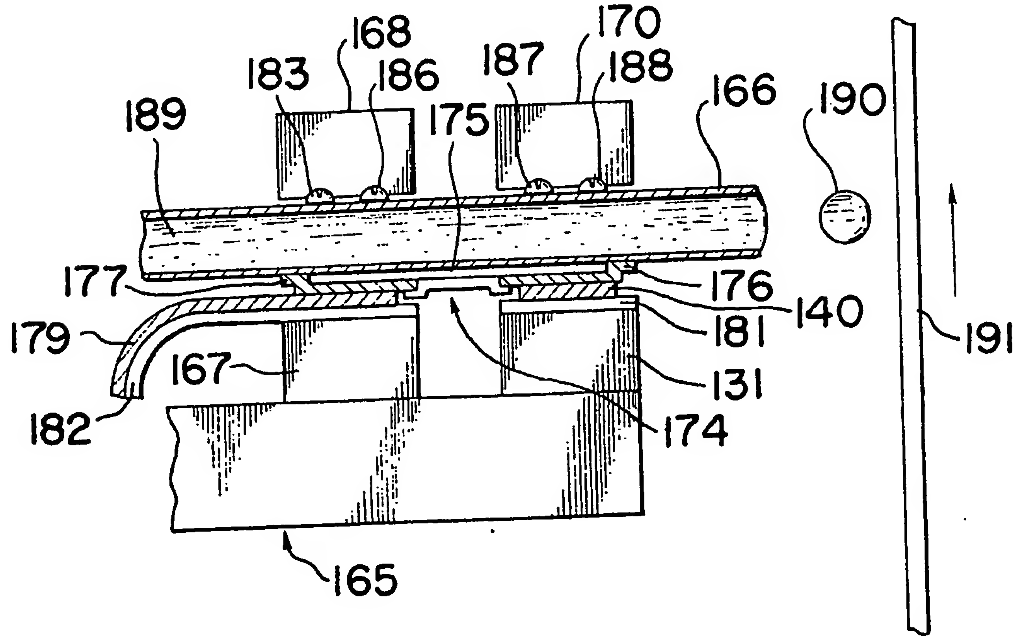

X"
168
172
170
169
166
173
Y"
171
178
165
167

FIG.29


168
170
183
186
187
188
166
190
189
175
177
176
140
179
181
191
167
131
182
174
165

SPECIFICATION
Liquid Jet Recording Process and Apparatus Therefor

Background of the Invention
Field of the Invention

The present invention relates to a liquid jet recording process and apparatus therefor, and more particularly to such process and apparatus in which a liquid recording medium is made to fly in a state of droplets.

Description of the Prior Art

So-called non-impact recording methods have recently attracted public attention in that the noise at the recording could be reduced to a negligible order. Among these particularly important is the so-called ink jet recording method allowing high-speed recording on a plain paper without particular fixing treatment, and in this field there have been proposed various approaches including those already commercialized and those still under development.

Such ink jet recording, in which droplets of a liquid recording medium, or usually called ink, are made to fly and to be deposited on a recording member to achieve recording, can be classified into several processes according to the method of generating said droplets and also to the method of controlling the direction of flight of said droplets.

A first process is disclosed for example in the United States Patent 3,060,429 (Teletype process) in which the liquid droplets are generated by electrostatic pull, and the droplets thus generated on demand are deposited onto a recording member with or without an electric-field control on the flight direction.

More specifically said electric-field control is achieved by applying an electric field between the liquid contained in a nozzle having an orifice and an accelerating electrode thereby causing said liquid to be emitted from said orifice and to fly between x—y deflecting electrodes so arranged as to be capable of controlling electric field according to the recording signals, and thus selectively controlling the direction of flight of droplets according to the change in the strength of electric field to obtain deposition in desired positions.

A second process is disclosed for example in the United States Patent 3,596,275 (Sweet process) and in the United States Patent 3,298,030 (Lewis and Brown process) in which a flow of liquid droplets of controlled electrostatic charges is generated by continuous vibration and is made to fly between deflecting electrodes forming a uniform electric field therebetween to obtain a recording on a recording member.

More specifically, in this process, a charging electrode receiving recording signals is provided in front of and at a certain distance from the orifice of a nozzle constituting a part of a recording head equipped with a piezo vibrating element, and a pressurized liquid is supplied into said nozzle while an electric signal of a determined frequency is applied to said piezo vibrating element to cause mechanical vibration thereof, thereby causing the orifice to emit a flow of liquid droplets. As the emitted liquid is charged by electrostatic induction by the above-mentioned charging electrode, each droplet becomes provided with a charge corresponding to the recording signal. The droplets having thus controlled charges are subjected to deflection corresponding to the amount of said charges during the flight in a uniform electric field between the deflecting electrodes in such a manner that only those carrying recording signals are deposited onto the recording member.

A third process is disclosed for example in the United States Patent 3,416,153 (Hertz process) in which an electric field is applied between nozzle and an annular charging electrode to generate a mist of liquid droplets by continuous vibration. In this process the strength of electric field applied between the nozzle and charging electrode is modulated according to the recording signals to control the pulverization of liquid thereby obtaining a gradation in the recorded image.

A fourth process, disclosed for example in the United States Patent 3,747, 120 (Stemme process), is based on a principle fundamentally different from that used in the foregoing three processes.

In contrast to said three processes in which the recording is achieved by electrically controlling the liquid droplets emitted from the nozzle during the flight thereof and thus selectively depositing only those carrying the recording signals onto the recording member, the Stemme process is featured in generating and flying the droplets only when they are required for recording.

More specifically, in this process, electric recording signals are applied to a piezo vibrating element provided in a recording head having a liquid-emitting orifice to convert said recording signals into mechanical vibration of said piezo element according to which the liquid droplets are emitted from said orifice and deposited onto a recording member.

The foregoing four processes, though being provided with respective advantages, are however associated with drawbacks which are inevitable or have to be prevented.

The foregoing first to third processes rely on electric energy for generating droplets or droplet flow of liquid recording medium, and also on an electric field for controlling the deflection of said droplets. For this reason the first process, though structurally simple, requires a high voltage for droplet

generation and is not suitable for high-speed recording as a multi-orificed recording head is difficult to make.

The second process, though being suitable for high-speed recording as the use of multi-orifice structure in the recording head is feasible, inevitably results in a structural complexity and is further associated with other drawbacks such as requiring a precise and difficult electric control for governing the flight direction of droplets and tending to result in formation of satellite dots on the recording element.

The third process, though advantageous in achieving recording of an improved gradation by pulverizing the emitted droplets, is associated with drawbacks of difficulty in controlling the state of pulverization, presence of background fog in the recorded image and being unsuitable for high-speed recording because of difficulty in preparing a multi-orificed recording head.

In comparison with the foregoing three processes the fourth process is provided with relatively important advantages such as a simpler structure, absence of liquid recovery system as the droplets are emitted on demand from the orifice of nozzle in contrast to the foregoing three processes wherein the droplets not having contributed have to be recovered, and a larger freedom in selecting the materials constituting the liquid recording medium not requiring electroconductivity in contrast to the first and second processes wherein said medium has to be conductive. On the other hand said fourth process is again associated with drawbacks such as difficulty in obtaining a small head or a multi-orificed head because the mechanical working of head is difficult and also because a small piezo vibrating element of a desired frequency is extremely difficult to obtain and inadequacy for high-speed recording because the emission and flight of liquid droplets have to be performed by the mechanical vibrating energy of the piezo element.

As explained in the foregoing, the conventional processes respectively have advantages and drawbacks in connection with the structure, applicability for high-speed recording, preparation of recording head, particularly of multi-orificed one, formation of satellite dots and formation of background fog, and their use has therefore been limited to the fields in which such advantages can be exploited.

Summary of the Invention

The principal object of the present invention, therefore, is to provide a liquid jet recording process and an apparatus therefor enabling the use of a simple structure, easy preparation of multiple orifices and a high-speed recording, and providing a clear image without satellite dots or background fog.

An another object of the present invention is to provide a liquid jet recording process for recording with liquid droplets and an apparatus therefor comprising the steps of:

Projecting a liquid from an orifice communicating with a thermal chamber by maintaining the same under pressure thereby forming a stream of said liquid directed toward a surface of a record-receiving member;

applying to the liquid contained in said thermal chamber a thermal energy generated according to electrical input signals by an electrothermal transducer coupled to said thermal chamber in such a manner as to transmit thermal energy to the liquid contained in said thermal chamber thereby instantaneously forming bubbles in said liquid, and applying a periodical force resulting from periodical state change involving instantaneous volumic change of said bubbles to said liquid stream thereby breaking up said stream into a succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said succession and either deflecting or intercepting said droplets thereby causing selective deposition onto said record-receiving member.

A still another object of the present invention is to provide a liquid jet recording process for recording with liquid droplets and an apparatus therefor comprising the steps of:

applying, each time a droplet is to be projected from an orifice communicating with a thermal chamber toward a surface of a record-receiving member, to a liquid contained in said thermal chamber a thermal energy generated corresponding to an instantaneous value of electrical input signals by an electrothermal transducer coupled to said thermal chamber in such a manner as to transmit the thermal energy to the liquid contained in said thermal chamber thereby instantaneously forming bubbles in said liquid, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between said chamber and said orifice; and

replenishing the thermal chamber with the liquid from a reservoir therefor when said force is instantaneously attenuated after the projection of droplet from said orifice.

A still another object of the present invention is to provide a liquid jet recording process for recording with liquid droplets and an apparatus therefor comprising the steps of:

projecting a liquid from an orifice communicating with a thermal chamber by maintaining the same under pressure thereby forming a stream of said liquid directed toward a surface of a record-receiving member;

applying to the liquid contained in said thermal chamber a thermal energy generated according to optical input signals by a photothermal transducer coupled to said thermal chamber in such a manner

as to transmit thermal energy to the liquid contained in said thermal chamber thereby instantaneously forming bubbles in said liquid, and applying a periodical force resulting from periodical state change involving instantaneous volumic change of said bubbles to said liquid stream thereby breaking up said stream into a succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said succession and either deflecting or intercepting said droplets thereby causing selective deposition onto said record-receiving member.

A still another object of the present invention is to provide a liquid jet recording process for recording with liquid droplets and an apparatus therefor comprising the steps of:

applying, each time a droplet is to be projected from an orifice communicating with a thermal chamber toward a surface of a record-receiving member, to a liquid contained in said thermal chamber a thermal energy generated corresponding to an instantaneous value of optical input signals by a photothermal transducer coupled to said thermal chamber in such a manner as to transmit the thermal energy to the liquid contained in said thermal chamber thereby instantaneously forming bubbles in said liquid, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between said chamber and said orifice; and

replenishing the thermal chamber with the liquid from a reservoir therefor when said force is instantaneously attenuated after the projection of droplet from said orifice.

Brief Description of the Drawings

Fig. 1 is a schematic view showing the principle of the present invention;

Figs. 2 to 5 are schematic views showing preferred embodiments of the present invention;

Figs. 6 and 7 are schematic views showing representative examples of recording head constituting a principal component in the present invention;

Figs. 8(a), (b) and (c) are schematic cross-sectional views of nozzles of other preferred recording heads;

Fig. 9 is schematic views of a preferred embodiment of multi-orificed recording head wherein (a), (b) and (c) are a front view, a lateral view and a cross-sectional view along the line X—Y in (b), respectively;

Fig. 10 is schematic view of an another preferred embodiment of multi-orificed recording head wherein (a) and (b) are a schematic perspective view and a cross-sectional view along the line X′—Y′ in (a), respectively;

Figs. 11 to 14 are views of a still another preferred embodiment of multi-orificed recording head wherein Fig. 11 is a schematic perspective view, Fig. 12 is a schematic front view, Fig. 13 is a partial cross-sectional view along the line X1—Y1 in Fig. 11 for showing the internal structure and Fig. 14 is a partial cross-sectional view along the line X2—Y2 in Fig. 13;

Fig. 15 is a chart showing the relationship between the energy transmission and the temperature difference ΔT between the surface temperature of heating element and the boiling temperature of liquid;

Fig. 16 is a block diagram showing an example of control mechanism for use in recording with a recording head shown in Fig. 6;

Fig. 17 is a block diagram showing an example of control mechanism for use in recording with a recording head shown in Fig. 11;

Fig. 18 is a timing chart showing the buffer function of a buffer circuit shown in Fig. 17;

Fig. 19 is a timing chart showing an example of the timing of signals to be applied to the elctro-thermal transducers shown in Fig. 17;

Fig. 20 is a view of an example of printing obtainable in the above-mentioned case;

Fig. 21 is a block diagram showing an another example of control mechanism for use in recording with a recording head shown in Fig. 11;

Fig. 22 is a timing chart showing the buffer function of a column buffer circuit shown in Fig. 21;

Fig. 23 is a timing chart showing an example of the timing of signals to be applied to the electro-thermal transducers in the case of Fig. 21;

Fig. 24 is a view of an example of printing obtainable in the above-mentioned case;

Figs. 25 to 27 are schematic perspective views of still other embodiments of the recording apparatus of the present invention;

Fig. 28 is partial perspective view of a still another preferred embodiment of the recording head constituting a principal component in the present invention; and

Fig. 29 is a cross-sectional view along the line X″—Y″ in Fig. 28.

Detailed Description of the Invention

The liquid jet recording process of the present invention is advantageous in easily allowing high-density multi-orifice structure enabling ultra-high speed recording, providing a clear image of improved quality without satellite dots or background fog, and further allowing arbitrary control on the quantity of projected liquid as well as the dimension of droplets through the control of thermal energy to be

applied per unit time. Also the apparatus embodying the abovementioned process is characterized in an extremely simple structure easily allowing minute working and thus enabling significant size reduction of the recording head itself constituting the essential part in the apparatus, also in the ease of obtaining a high-density multi-orifice structure indispensable for high-speed recording based on said simple structure and easy mechanical working, and further in the freedom of designing the orifice array structure in any desired shape in preparing a multi-orificed head enabling to easily obtain a recording head in a form of a full-line bar.

Outline of the Invention

The outline of the present invention will be explained in the following with reference to Fig. 1 which is an explanatory view showing the basic principle of the present invention.

In a nozzle 1 there is supplied a liquid 3 under a determined pressure P generated by a suitable pressurizing means such as a pump, said pressured being either enough for causing said liquid to be emitted from an orifice 2 against the surface tension of said liquid at said orifice or not enough for causing such emission. If a thermal energy is applied to the liquid 3a present in a portion of a width Δl (thermal chamber portion) located in said nozzle 1 at a distance l from the orifice 2 thereof, a vigorous state change of said liquid 3a causes the liquid 3b contained in the width l of nozzle 1 to be projected partly or substantially entirely, according to the quantity of thermal energy applied, from said orifice 2 and to fly toward a record-receiving member 4 for deposition in a determined position thereon.

More specifically the liquid 3a present in said thermal chamber portion Δl, when subjected to thermal energy, causes an instantaneous state change of forming bubbles at a side thereof receiving said thermal energy, and the liquid 3b present in the width l is partly or substantially entirely projected from the orifice 2 by means of the force resulting from said state change. Upon termination of supply of thermal energy or upon immediate replenishment of liquid of an amount emitted, the bubbles formed in the liquid 3a are instantaneously reduced in size and vanish or contract to a negligible dimension.

The liquid of an amount corresponding to the emitted amount is replenished into the nozzle 1 by volumic contraction of bubbles or by a forced pressure.

The dimension of droplets 5 projected from the orifice 2 depend on the quantity of thermal energy applied, width Δl of the portion 3a subjected to the thermal energy in the nozzle 1, internal diameter d of nozzle 1, distance l from the orifice 2 to the position of action of said thermal energy, pressure P of the liquid, and specific heat, thermal conductivity and thermal expansion coefficient of the liquid. It is therefore easily possible to control the dimension of the droplets 5 by changing one or two of these factors and thus to obtain a desired diameter of droplet or spot on the record-receiving member 4. Particularly a change in a distance l, namely in the position of action of thermal energy during the recording allows to arbitrarily control the size of droplets 5 projected from the orifice 2 without altering the quantity of thermal energy applied per unit time, thereby allowing to easily obtain an image with gradation.

According to the present invention, the thermal energy to be applied to the liquid 3a present in the thermal chamber portion Δl of the nozzle 1 may either be continuous in time or be intermittent pulsewise.

In case of pulsewise application it is extremely easy to control the size of droplets and the number thereof generated per unit time through suitable selection of the frequency, amplitude and width of pulses.

Also in case of energy application uncontinuous in time, the thermal energy to be applied may be modulated with the information to be recorded. Namely by applying thermal energy pulsewise according to the recording information signals it is rendered possible to cause all the droplets 5 emitted from the orifice 2 to carry recording information and thus to achieve recording by depositing all such droplets onto the record-receiving member 4.

On the other hand, in case of uncontinuous energy application without modulation by the recording information, the thermal energy is preferably applied repeatedly with a certain determined frequency.

The frequency in such case is suitably selected in consideration of the species and physical properties of the liquid to be employed, shape of nozzle, liquid volume contained in the nozzle, liquid supply speed into the nozzle, diameter of orifice, recording speed etc, and is generally selected within a range from 0.1 to 100 KHz, preferably from 1 to 1000 KHz and most preferably from 2 to 500 KHz.

The pressure applied to the liquid 3 in this case may be selected either at a value causing emission of liquid 3 from the orifice 2 even in the absence of effect of said thermal energy, or at a value not causing such emission if without said thermal energy. In either case it is possible to cause projection of a succession of droplets of a desired diameter at a desired frequency by repeated volumic changes resulting from bubble formation of the liquid 3a in the thermal chamber portion Δl under the effect of thermal energy or by a vibration resulting from repeated volumic changes in thus formed bubbles.

The liquid droplets projected in the above-explained manner are subjected to control by electrostatic charge, electric field or air flow according to the recording information to achieve recording.

In case of thermal energy application continuous in time, the size of droplets and the number thereof generated per unit time are, as confirmed by the present inventors, principally determined by the amount of thermal energy applied per unit time, pressure P applied to the liquid present in the nozzle 1, specific heat, thermal expansion coefficient and thermal conductivity of said liquid and the energy required for causing the droplet to be projected from the orifice 2. It is therefore possible to control said size and number of droplets by controlling, among the above-mentioned factors, the amount of thermal energy per unit time and/or the pressure P.

In the present invention the thermal energy applied to the liquid 3 is generated by supplying a thermal transducer with a suitable energy. Said energy may be in any form as long as it is convertible to thermal energy, but preferably is in the form of electric energy in consideration of ease of supply, transmission and control, or in the form of energy from a laser in consideration of the advantages such as a high converting efficiency, possibility of concentrating a high energy into a small target area, possibility of structural miniaturization and ease of supply, transmission and control.

In case of using electric energy the above-mentioned transducer is an electrothermal transducer which is provided, either in direct contact or via a material of a high thermal conductivity, on the internal or external wall of the thermal chamber portion Δl of the nozzle 1 in such a manner that the liquid 3a can be effectively subjected to the thermal energy generated by said electrothermal transducer provided at least in a portion of the internal or external wall of said thermal chamber portion.

In case of using laser energy, the above-mentioned transducer may be the liquid 3 itself or may be an another element provided on said nozzle 1.

For example a liquid 3 containing a material generating heat upon absorption of laser energy directly absorbs the laser energy to cause a state change by the resulting heat, thereby causing the projection of droplets from the nozzle 1. Also for example a layer generating heat upon absorption of laser energy, if provided on the external surface of nozzle 1, transmits the heat generated by the laser energy through the nozzle 1 to the liquid 3, thereby causing a state change therein and thus projecting droplets from the nozzle 1.

The record-receiving member 4 adapted for use in the present invention can be any material ordinarily used in the technical field of the present invention.

Examples of such record-receiving member are paper, plastic sheet, metal sheet and laminated materials thereof, but particularly preferred is paper in consideration of recording properties, cost and handling. Such paper can be, for example, ordinary paper, pure paper, light-weight coated paper, coated paper, art paper etc.

Detailed Description of the Preferred Embodiments

Now there will given a detailed explanation on the preferred embodiments of the present invention, while making reference to the attached drawings.

Referring to Figure 2 showing in a schematic view an embodiment suitable for droplet on-demand recording utilizing electric energy as the source of thermal energy, the recording head 6 is provided, on a fixed position on the nozzle 7, with an electrothermal transducer 8 such as a so-called thermal head encircling the thermal chamber portion. The nozzle 7 is supplied with a liquid recording medium 11 from a liquid reservoir 9 under a predetermined pressure through a pump 10 if necessary.

A valve 12 is provided to control the flow rate of liquid 11 or to block the flow thereof to the nozzle 7.

In the embodiment of Figure 2 the electrothermal transducer 8 is provided at a determined distance from the front end of nozzle 7 and in intimate contact with the external wall thereof, and said contact can be made more effective by interposing a material of a high thermal conductivity therebetween or by preparing the nozzle itself with a material of a high thermal conductivity.

Though in said embodiment the electrothermal transducer 8 is fixedly mounted on the nozzle 7, it is also possible to suitably control the size of droplets of liquid 11 projected from the nozzle 7 by rendering said transducer displaceable on the nozzle 7 or by providing additional electrothermal transducers in other positions.

The recording in the embodiment shown in Figure 2 is achieved by supplying recording information signals to a signal processing means 14 and to convert said signals into pulse signals, and applying thus obtained pulse signals to the electrothermal transducer 8.

Upon receipt of said pulse signals corresponding to said recording information signals, the electro-thermal transducer 8 instantaneously generates heat which is applied to the liquid 11 present in the thermal chamber portion coupled with said transducer 8. Under the effect of thermal energy the liquid 11 instantaneously undergoes a state change which causes the liquid 11 to be projected from an orifice 15 of the nozzle 7 in the form of droplets 13 and to be deposited on a record-receiving member 16.

The size of droplets 13 projected from said orifice 15 depends on the diameter of orifice 15, quantity of liquid present in the nozzle 7 and in front of the position of electrothermal transducer 8, physical properties of the liquid 11 and the magnitude of electric pulse signals.

Upon projection of droplets 13 from the orifice 15 of nozzle 7, the nozzle 7 is replenished, from

the reservoir 9, with the liquid of an amount corresponding to the projected amount. In this case the time required for said replenishment has to be shorter than the interval between succeeding electric pulses.

After a part of substantially all of the liquid present from the position of electrothermal transducer 8 to the front end of nozzle 7 is emitted therefrom by a state change in said thermal chamber portion upon transmission of thermal energy from said transducer 8 to the liquid 11, and simultaneously with the instantaneous replenishment of liquid from the reservoir 9 through a pipe, the area in the vicinity of said electrothermal transducer 8 proceeds to resume the original thermal stationary state until a next electrical pulse signal is applied to the transducer 8.

In case the recording head 6 is composed of a single head as shown in Figure 2, a scanning for recording can be achieved by selecting the displacing direction of the recording head 6 orthogonal to that of record-receiving member 16 in the plane thereof, and in this manner it is rendered possible to achieve recording on the entire surface of the record-receiving member 16. Further the recording speed can be increased by the use of a multi-orifice structure in the recording head 6 as will be explained later, and the displacement of recording head 6 during the recording can be eliminated by the use of a full-line bar structure in which a number of nozzles are arranged in a line over a width required for recording on the record-receiving member 16.

The electrothermal transducer 8 can be almost any transducers capable of converting electrical energy into thermal energy, but particularly suitable is so-called thermal head which has recently been employed in the field of heat-sensitive recording.

Such electrothermal transducers are simply capable of generating heat upon receiving an electric current, but a more effective on-off function of thermal energy to the recording medium in response to the recording information signals can be expected by the use of electrothermal transducers showing so-called Peltier effect, namely capable of heat emission by a current in one direction and heat absorption by a current in the opposite direction.

Examples of such electrothermal transducers are a junction element of Bi and Sb, and a junction element of $(Bi \cdot Sb)_2Te_3$ and $Bi_2(Te \cdot Se)_3$.

Also effective as the electrothermal transducer is the combination of a thermal head and a Peltier effect element.

Now referring to Figure 3, showing an another preferred embodiment of the present invention, the recording head 17 is provided, in a similar manner as shown in Figure 2, with an electrothermal transducer 19 on the nozzle 18 so as to encircle the thermal chamber portion, said nozzle 18 being provided with an orifice 20 of a determined diameter for emitting the liquid 21.

The recording head 17 is connected to a liquid reservoir 22 through a pump 23 and a pipe to apply a desired pressure to the liquid 21 contained in said nozzle 18 thereby forming a stream 24 of liquid emitted from the orifice 20 toward a surface of a record-receiving member 26.

An electric actuator 25 releasing electric pulse signals for driving the electrothermal transducer 19 is connected thereto thereby forming liquid droplets 27 at a determined time interval.

Between said recording head 17 and record-receiving member 26 and at a small distance from the front end of nozzle 18 there are provided a charging electrode 28 for charging thus formed droplets 27 and deflecting electrodes 30 for deflecting the flight direction of said droplets 27 according to the amount of charge thereof, said electrodes being arranged in such a manner that the center thereof coincides with the central axis of the nozzle 18. Also in a determined position between the deflecting electrodes 30 and record-receiving member 26 there is provided a gutter 31 for recovering the droplets 29 not utilized for recording. The droplets recovered in said gutter 31 is returned through a filter 32 to the reservoir 22 for reuse, said filter 32 being provided for removing foreign matters which may affect the recording for example by clogging the nozzle 18 from the recording medium recovered by the gutter 31.

Said charging electrode 28 is connected to a signal processing means for processing the input information signals and applying thus obtained output signals to said charging electrode 28.

Upon receipt of electrical pulse signals of a desired frequency from the electric actuator 25, the electrothermal transducer 19 accordingly applied thermal energy to the liquid contained in said thermal chamber portion to periodically cause instantaneous state change therein, and a periodic force resulting therefrom is applied to the aforementioned stream of liquid 24. As the result said stream is broken up into a succession of equally spaced droplets of a uniform diameter. At the moment of separation from said stream 24, each droplet becomes charged selectively according to the recording signals by said charging electrode 28. The droplets 27 thus charged upon passing the charging electrode 28 fly toward the record-receiving member 26, and, upon passing the space between the deflecting electrodes 30, are deflected according to the amount of charge thereon by an electric field formed between said electrodes 30 by means of a high-voltage source 34, whereby only the droplets required for recording are deposited on said member 26 to achieve desired recording.

The droplets deposited on the record-receiving member 26 can be those carrying the electrostatic charge or those not carrying the charge by suitably controlling the timing of droplet formation and the timing of application of signal voltages to the charging electrode 28.

In case the droplets used for recording are those not carrying charges, it is preferable that the droplets are projected in the direction of gravity and other associated means are arranged accordingly.

Figure 4 schematically shows a still another preferred embodiment of the present invention which is basically same as that shown in Figure 2 except the use of energy of laser light as the source of thermal energy and the structural difference resulting therefrom.

A laser beam generated by a laser oscillator 40 is pulse modulated in a beam modulator 41 according to the recording information signals which are in advance electrically processed in a modulator actuating circuit 42. Thus modulated laser beam passes through a scanner 43 and is focused, by a condenser lens 44, onto a predetermined position of a nozzle 36 constituting a part of the recording head 35, there heating the irradiated portion of nozzle 36 and/or directly heating the liquid 45 contained in said nozzle 36.

In case of focusing the laser beam on the wall of nozzle 36 and applying thus generated thermal energy to the liquid 44 contained in said nozzle 36 to cause a state change, it is advantageous to compose the irradiated portion of nozzle 36 with a material capable of effectively absorbing the laser light to generate heat, or to coat or wrap the external surface of nozzle 36 with such a material.

As an example, the irradiated portion of nozzle 36 can be coated with an infrared-absorbing and heat-generating material such as carbon black combined with a suitable resinous binder.

The embodiment shown in Figure 4 is particularly featured in that the size of droplets 46 projected from the nozzle 36 can be arbitrarily controlled by changing the position of irradiation of laser beam by means of the scanner 43, whereby the density of image formed on the record-receiving member 39 can be arbitrarily controlled.

An other advantage lies in a fact that the recording is not affected by the eventual charge present on the record-receiving member 39 resulting from the displacement thereof, since the droplets 46 are projected from the orifice 37 according to the information signals and are deposited onto the record-receiving member 39 without intermediate charging. This advantage is similarly obtainable in the embodiment of Figure 2.

A still another advantage lies in a fact that the recording head 35 can be of an extremely simple structure and of a low cost since the laser energy, which is in fact an electromagnetic energy, can be applied to the nozzle 36 and/or liquid 45 without any mechanical contact. This advantage is particularly manifested in case of using a multiorificed recording head 35.

In such multi-orificed recording head, the present embodiment is particularly advantageous also for the maintenance of head, since the thermal energy can be applied to the liquid in each nozzle simply by irradiating each of plural nozzles with a laser beam instead of providing complicated electric circuits to each of said nozzles.

As the beam modulator 41 there can be employed various modulators ordinarily used in the field of laser recording, but for a high-speed recording particularly suitable are an acousto-optical modulator (AOM) and an electro-optical modulator (EOM). These modulators can be achieved as an external or an internal modulator in which the modulator is placed outside or inside the laser oscillator, either of which is employable in the present invention.

The scanner 43 can either be a mechanical one or an electronic one and suitably selected according to the recording speed.

Examples of such mechanical scanner are a galvanometer, an electrostriction element or a magnetrostriction element coupled with a mirror and a high-speed motor coupled with a polygonal rotary mirror, a lens or a hologram, the former and the latter being respectively suitable for a low-speed and a high-speed recording.

Also the examples of such electronic scanner are an acousto-optical element, an electro-optical element, a photo-IC element.

Figure 5 schematically shows a still another preferred embodiment of the present invention which is basically same as that shown in Figure 3 except for the use of energy of laser light as the source of thermal energy and the accompanying differences in structure, but is provided with various advantages as enumerated in connection with the embodiment shown in Figure 4.

In Figure 5, a recording head 47 is composed of nozzle 48 provided with an orifice 49 for projecting a liquid recording medium 50, which is supplied into said recording head 47 from a reservoir 51 under a determined pressure by means of a pump 52.

The recording with the apparatus shown in Figure 5 can be achieved by modulating a laser beam generated by a laser oscillator 54 with a beam modulator 55 into light pulses of a desired frequency, and focusing said light pulses onto a determined position (thermal chamber portion) of the recording head 47 by means of a scanner 56 and a condenser lens 57.

Upon heat generation by adsorption of laser energy, the liquid 50 contained in said thermal chamber portion instantaneously forms bubbles thereby periodically undergoing a state change involving volumic change of said bubbles, and the periodic force resulting therefrom is applied to a stream of liquid emitted from the orifice 49 under the above-mentioned pressure at a determined frequency thereby breaking up said stream into a succession of equally spaced droplets of a uniform diameter.

Each droplet, at the moment of separation thereof from the stream 53 by the force resulting from

the state change of liquid 50 caused by the heating effect of laser light, is charged by a charging electrode 58 according to the recording information signals.

The amount of charge on said droplet is determined by a signal obtained by processing the recording information signals in a signal processing means 59 and supplied to the charging electrode 58. After emerging from said electrode 58, the droplet is deflected according to the charge thereon, when it passes through a space between deflecting electrodes 60, by means of an electric field created therebetween by a high-voltage source 61.

In Figure 5 the droplets deflected by said deflecting electrodes 60 are deposited on a record-receiving member 63 while those not deflected encounter and are recovered by a gutter 62 for reuse.

The recording medium captured in the gutter 62 is returned to the reservoir 51 after removal of foreign matters by a filter 64.

In the embodiment shown in Figure 5, it is also possible, if desired, to guide the laser beam generated by the laser oscillator 54 directly to the determined position of the recording head 47, omitting the beam modulator 55, scanner 56 and condenser lens 57. Also the laser oscillator 54 may either be a continuous oscillation type or a pulse oscillation type.

Figure 6 schematically shows a still another preferred embodiment of the present invention, in which a recording head 65 is provided with an orifice 66 for projecting a liquid recording medium, an orifice 67 for introducing said medium, and an electrothermal transducer 69 on the external surface of wall 70 of a thermal chamber portion 68 where the liquid recording medium undergoes a state change under the effect of thermal energy.

Said electrothermal transducer 69 is generally composed of a heat-generating resistor 71 provided on the external wall of said wall 70, electrodes 72, 73 provided on respective ends of said resistor 71 for supplying a current thereto, an anti-oxidation layer 73 as a protective layer provided on said resistor 71 to prevent oxidation thereof, and eventually an anti-abrasion layer 75 for preventing damages resulting from mechanical abrasion, if necessary.

Examples of material adapted for forming said heat-generating resistor 71 are tantalum nitride, nichrome, silver-paradium alloy, silicon semiconductor, and borides of metals such as hafnium, lanthanum, zirconium, titanium, tantalum, tungsten, molybdenum, niobium, chromium or vanadium.

Among the above-mentioned materials particularly preferred are metal borides in which the preference is given in the decreasing order of hafnium boride, zirconium boride, lanthanum boride, tantalum boride, vanadium boride and niobium boride.

Said resistor 71 can be prepared from the above-mentioned materials by means for example of electron beam evaporation or sputtering.

The thickness of said resistor 71 is determined in relation to the surface area thereof, material, shape and dimension of thermal chamber portion Δl, actual power consumption etc. so as to obtain a desired heat generation per unit time, and is generally in a range of 0.001 to 5 μ, preferably 0.01 to 1μ.

The electrodes 72 and 73 can be composed of various materials ordinarily used for forming such electrodes, for example metals such as Al, Ag, Pu, Pt, Cu, etc, and can be prepared for example by evaporation with desired size, shape and thickness in a desired position.

Said anti-oxidation layer 74 is for example composed of SiO_2 and can be prepared for example by sputtering.

The anti-abrasion layer 75 is for example composed of Ta_2O_5 and can also be prepared for example by sputtering.

The nozzle 76 can be composed of almost any material capable of effectively transmitting the thermal energy from the electrothermal transducer 69 to the liquid recording medium 80 contained in said nozzle 76 without undergoing irreversible deformation by said thermal energy. Representative examples of such preferred material are ceramics, glass, metals, heat-resistant plastics etc. Particularly glass is preferable because of easy working and adequate thermal resistance, thermal expansion coefficient and thermal conductivity.

For effective projection of the liquid recording medium from the orifice 66, the material constituting the nozzle 76 should preferably be provided with a relatively small thermal expansion coefficient.

As an example the electrothermal transducer 69 can be obtained by subjecting a pretreated glass nozzle to sputtering of $ZrBr_2$ in a thickness of 800 Å to form a heat-generating resistor, then to formation of aluminum electrodes of a thickness of 500 μm by masked evaporation, and to sputtering of an SiO_2 protective layer in a thickness of 2 μm and with a width of 2 mm so as to cover said resistor.

In this example the nozzle 76 is composed of a glass fiber cylinder with an internal diameter of 100 μ and a thickness of 10 μ, but said nozzle need not necessarily be cylindrical as will be explained later.

An orifice 66 of a diameter of 60 μ integral with said nozzle 76 is formed by heat melting thereof, but the orifice may also be prepared as a separate piece for example by boring a glass plate with an electron beam or a laser beam and then combined with the nozzle 76. Such method is particularly useful in case of preparing a head provided with plural thermal chamber portions and with plural orifices.

The circumference of said orifice 66 and particularly the external surface therearound should

preferably provided with a water-repellent or oil-repellent treatment, respectively when the liquid recording medium is aqueous or nonaqueous, in order to prevent the liquid medium leaking from the orifice and wetting the external surface of nozzle 76.

The material for such treatment should be suitably selected according to the material of nozzle and the nature of liquid recording medium, and various commercially available materials can be effectively used for this purpose. Examples of such material are FC-721 and FC-706 manufactured by 3M Company.

In the illustrated embodiment the rear orifice 67 extends 10 mm backward from the center of heat-generating resistor and is connected to a pipe 79 for supplying the liquid 80 from the reservoir 78, but may also be of a constricted shape with a cross-section smaller than that of the thermal chamber portion in order to reduce backward pressure transmission.

Upon application between the electrodes 72 and 73 of a pulse voltage generated by an actuating circuit 77 for electrically driving said electrothermal transducer 69, the resistor 71 generates heat which is transmitted through the wall 70 to the liquid recording medium 80 supplied to the nozzle 76 from the reservoir 78 through the pipe 79. Upon receipt of said thermal energy the liquid recording medium present in the thermal chamber portion 68 at least reaches the internal gasification temperature to generate bubbles in said thermal chamber portion. The instantaneous volumic increase of said bubbles applies, from the side of said portion, a pressure which is in excess of the surface tension of said medium at the orifice, whereby said medium is projected from the orifice 66 in a form of droplets. The resistor 71 terminates heat generation simultaneously with the trailing down of the pulse voltage whereby the bubbles reduce in volume and vanish and the thermal chamber portion 68 becomes filled with the replenishing liquid medium. In this manner it is possible to repeat the formation and vanishing of bubbles in the portion 68 with repeated emissions of droplets from the orifice 66 by applying, in succession, pulse voltages generated by the actuating circuit 77 to the electrodes 72, 73.

In case of fixing the electrothermal transducer 69 on the nozzle 76 as in the recording head 65 shown in Figure 6, there may be provided plural transducers on the external surface of nozzle 76 in order to allow a change in the functioning position of thermal energy. Also the use of a structure having a resistor 71 divided into plural portions and provided with corresponding plural lead electrodes will enable to obtain a suitable heating capacity distribution by supplying electric current to at least two electrodes selected appropriately, thereby allowing to not only modify the dimension and position of functioning area of thermal energy but also to regulate the heat generating capacity.

Though in Figure 6 the electrothermal transducer 69 is provided only on one side of the nozzle 76, it may also be provided on both sides or along the entire circumference of the nozzle 76.

When the recording head 65 of Figure 6 prepared in the above-explained manner is used in the apparatus shown in the block diagram of Figure 16, a clear image could be obtained by applying pulse signals to the electrothermal transducer according the image signals while supplying the liquid recording medium under a pressure of a magnitude not causing emission thereof from the orifice 66 when the resistor 71 does not generate heat.

Now referring to Figure 16 showing the block diagram of the above-mentioned apparatus, an input sensor 119 composed for example of a photodiode receives image information signals which, after processing in a processing circuit 120, are supplied to a drive circuit 121 which drives the recording head 65 by modifying the width, amplitude and frequency of pulses according to the input signals.

For example, in a most simple recording, the processing circuit 120 identifies the black and white of the input image signals and supplies the results to the drive circuit 121, which generates signals of a controlled frequency for obtaining a desired droplet density and of a pulse width and a pulse amplitude for obtaining an adequate droplet size thereby controlling the recording head 65.

Also in case of a recording involving gradation, it is also possible to modulate the droplet size or the number of droplets as explained in the following.

In case of recording with variable droplet size, the drive circuit 121 is provided with plural circuits each releasing drive pulse signals of determined width and amplitude corresponding to a determined droplet size, and the processing circuit 120 processes the image signals received by the input sensor 119 and identifies a circuit to be used among said plural circuits. Also in the recording with variable number of droplets, the processing circuit 120 converts the input signals received by the input sensor 119 to digital signals, according to which the drive circuit 121 drives the recording head 65 in such a manner that the number of droplets per unit input signal is variable.

Also in a recording with a similar apparatus it was confirmed that droplets of a number corresponding to the applied frequency could be stably projected with a uniform diameter by applying repeating pulse voltages to the electro-thermal transducer 69 while supplying the liquid recording medium 80 to the recording head 65 under a pressure of a magnitude causing overflow of said medium from the orifice 66 when the resistor 71 is not generating heat.

From the foregoing results the recording head 65 shown in Figure 6 is identified extremely effective for continuous droplet projection at a high frequency.

Furthermore, the recording head shown in Figure 6 and constituting a principal portion of the present invention, being very small in size, can be easily formed into a unit of multiple nozzles, thereby

obtaining a high-density multi-orificed recording head. In such case the supply of liquid recording medium can be achieved not by plural means individually corresponding to said nozzles but by a common means serving to all these nozzles.

Now Figure 7 schematically shows a basic embodiment of the recording head adapted for use when the energy of laser is employed as the source of thermal energy.

The recording head 81 is provided, on the external surface of nozzle 82, with a photothermal transducer 83 for generating thermal energy upon absorption of laser energy and supplying said thermal energy to a liquid contained in the nozzle 82. Said photothermal transducer or converter 83 is provided in case said liquid is incapable of causing a state change enough for projecting the liquid from an orifice 84 upon heat generation by absorption of laser energy by said liquid itself or in case said liquid undergoes no or almost no laser energy absorption and heat generation as explained above, and may therefore be dispensed with if said liquid itself is capable of generating heat, upon absorption of laser energy, to undergo a state change enough for causing projection of the liquid from the orifice 84.

For example in case of using an infrared laser as the source of laser energy, the photothermal transducer 83 can be composed of an infrared-absorbing heat-generating material which, if provided with enough film-forming and adhering properties, can be directly coated on a determined portion on the external wall of nozzle 82; or, if not provided with such properties, can be coated after being dispersed in a suitable heat- resistant binder having such film-forming and adhering properties. As such infrared absorbing material there can be employed the infrared absorbing materials mentioned in the foregoing as the additive to the liquid. Also the preferred examples of said binder are heat-resistant fluorinated resins such as polytetrafluoroethylene, polyfluoroethylenepropylene, tetrafluoroethyleneperfluoroalkoxy-substituted perfluorovinyl copolymer etc, and other synthetic heat-resistant resins.

The thickness of said photothermal transducer 83 is suitably determined in relation to the strength of laser energy to be employed, the heat-generating efficiency of the photothermal transducer to be formed, the species of liquid to be employed etc, and is generally selected within a range of 1 to 1000 μ, preferably 10 to 500 μ.

When said photothermal transducer is to be provided, the nozzle is to be made of a material having suitable thermal conductivity and thermal expansion coefficient, and is preferably designed so as to allow substantially all the thermal energy generated be transmitted to the recording medium present directly under the portion irradiated with the laser energy, for example by a thin wall structure.

Figure 8 shows, in cross-sectional views, still other recording heads adapted for use in the present invention. A recording head 85 shown in Figure 8(a) is provided, inside a nozzle 86, with plural hollow tubes 87, for example fiber glass tubes, each tube being supplied with the liquid. This recording head 85, being capable of controlling the size of droplet to be emitted from the orifice of nozzle 86 in response to the amount of thermal energy applied, is featured in providing a recorded image with an excellent gradation by controlling the amount of thermal energy to be applied according to the recording information signals.

The liquid recording medium emitted from the orifice of nozzle 86 is supplied from a part of hollow tubes in the nozzle when the amount of applied thermal energy is small, while the liquid medium contained in all the hollow tubes 87 is emitted from the nozzle 86 when the amount of applied thermal energy is sufficiently large.

Although in Figure 8(a) the nozzle 86 is provided with a circular cross-section, it is by no means limited to such shape but may also assume other cross-sectional shapes such as square, rectangular or semi-circular shape. Particularly when a thermal transducer is provided on the external surface of the nozzle 86, the external surface should preferably be provided with a planar portion at least in the position of said transducer in order to facilitate mounting thereof.

The recording head shown in Figure 8(b) is, different from that shown in Figure 8(a), provided with plural filled circular rods 89 inside the nozzle 89. This structure allows to increase the mechanical strength of the nozzle 84 when it is made of a relatively breakable material such as glass.

In said recording head 88 the liquid recording medium is supplied into the spaces 91 inside the nozzle 89 and emitted therefrom upon receipt of thermal energy.

The recording head 92 shown in Figure 8(c) is composed of a member 93 in which a recessed groove is formed for example by etching, and a thermal transducer 94 covering the open portion of said groove. This structure allows to reduce the loss of thermal energy as it is directly applied from the transducer to the recording medium.

It is to be noted that the cross-sectional structure shown in Figure 8(c) need not be same as illustrated in the entirety thereof as long as the portion of recording head 88 for mounting the transducer 94 is structured as illustrated. Stated differently, in the vicinity of orifice of recording head 88 for emitting the liquid recording medium, the member 93 may be provided with a rectangular or circular hollow structure instead of a grooved shape.

The structure of recording head in the present invention, particularly that employing laser energy as the source of thermal energy, being substantially simpler than that of conventional recording heads, allows various designing of recording head and nozzle thereof, with the resulting improvement in the quality of recorded image.

Particularly in the present invention it is extremely easy to obtain a multi-nozzled recording head with a simple structure, which is greatly advantageous in mechanical working and mass production.

Figure 9 shows a preferred embodiment of a multi-orificed recording head, wherein (a), (b) and (c) are respectively a schematic front view of the orifice side for projecting the liquid recording medium of a recording head 95, a schematic lateral view thereof and a schematic cross-sectional view thereof along the line X—Y.

Said recording head 95 is provided with 15 nozzles which are arranged in a line in the portion X—Y as shown in Figure 9(c) but of which orifices are arranged in three rows by five columns (a1, a2, a3, b1, ... e1, e2, e3) as shown in Figure 9(a). The recording head of such structure is particularly suitable for high-speed recording, as the recording can be achieved with a relatively small displacement of the head, or even without any displacement thereof if the number of nozzles is further increased.

Furthermore said recording head is featured in that the mounting of 15 electrothermal transducers 97 to the nozzles is facilitated as said nozzles are arranged in line in the portion X—Y.

Although the mounting of electrothermal transducers to the nozzles is difficult if the nozzles receiving said transducers are arranged as shown in Figure 9(a) and the complicated structure will pose a problem in the production technology even if the mounting itself is possible, the aligned arrangement of the portion X—Y of nozzles as shown in Figure 9(c) allows the mounting of electrothermal transducers (A1, A2, ..., B1, ..., C1, ..., D1, ..., E1, ...) to said nozzles with a technical facility similar to that in case of preparing a single-head recording head.

Also the electric wirings to the electrothermal transducers 97 can be achieved in a substantially same manner as in a single-nozzle recording head.

In the structure of recording head 95 shown in Figure 9, the nozzles are arranged, in the X—Y portion receiving said electrothermal transducers 97, in the order of a1, a2, a3, b1, b2, b3, c1, c2, c3, d1, d2, d3, e1, e2 and e3 corresponding to the arrangement of orifices shown in Figure 9(a), but it is also possible to employ an arrangement in the order of a1, b1, c1, a2, b2, c2, a3, b3, c3, a4, b4, c4, a5, b5 and c5. Thus the order of arrangement of nozzles can be suitably selected according to the scanning method used in the recording.

In case the distance between the nozzles in the portion X—Y is very small and there exists a possibility of crosstalk between the adjacent nozzles, namely an effect of thermal energy developed by an electrothermal transducer to the neighboring nozzle, it is also possible to provide a heat insulator in each space between the neighboring nozzles and transducers. In this manner each nozzle receives only the thermal energy generated by an electrothermal transducer attached thereto, and it is rendered possible to obtain an improved recorded image without so-called fogging.

Although a checkerboard arrangement is employed for the orifices of recording head 95 shown in Figure 9, it is also possible to adopt other arrangements therefor, for example a dislodged grating arrangement or an arrangement in which the number of nozzles in each row varies.

Figure 10 shows a still another embodiment of a recording head adapted for use in the present invention, wherein (a) and (b) are respectively a schematic perspective view of a recording head 98 and a schematic cross-sectional view thereof along the dotted line X′—Y′.

The recording head 98 is of a multi-orifices structure composed of a linear combination of plural single-orifice recording heads each comprising a nozzle 99 having an orifice 100, a thermal chamber 101 connected to said nozzle 99, a supply channel 102 for introducing the liquid recording medium into said nozzle 99, and an electrothermal transducer 103. The electrothermal transducer of each single-orifice recording head constituting the recording head 98 is respectively supplied with energy to cause emission of droplets of said recording medium from each orifice.

Said recording head 98 is featured in the presence of the thermal chamber 101 of which volume is relatively larger than that of nozzle 99 and which is provided in the rear face with the electrothermal transducer 103, whereby the response is improved as the volume of recording medium undergoing a state change under the influence of thermal energy becomes larger.

In case of using laser energy as the source of thermal energy, the above-mentioned electrothermal transducer is naturally replaced by a photothermal transducer. However it is also possible to cause a state change, even without said photothermal transducer, for example by irradiating said thermal chamber in the rear face thereof with a laser beam to apply thermal energy directly to the liquid recording medium contained in said thermal chamber 101.

Now referring to Figures 11—14, there will be explained a still another preferred embodiment of the recording head constituting a principal portion of the present invention, wherein Figure 11 is a schematic perspective view of a multi-orificed recording head 104, Figure 12 is schematic elevation view of said recording head, Figure 13 is a partially cut-off cross-sectional view along the line X1—Y1 in Figure 11 showing internal structure of said head, and Figure 14 is a partially cut-off cross-sectional view along the line X2—Y2 in Figure 13 for explaining a planar structure of the electrothermal transducers employed in the recording head shown in Figure 11.

In Figure 11 the recording head 104 is provided with seven orifices 105 for the purpose of clarity, but the number of orifices is not limited thereto and can be arbitrarily selected from one to any desired

number. Also the multi-orificed recording head may be provided with a multi-array arrangement of orifices instead of single-array arrangement shown in Figure 11.

The recording head 104 shown in Figure 11 is composed of a base plate 106 and a cover plate 107 which is provided with seven grooves and of which grooves surface is affixed onto a front end portion of said base plate 106 to form seven nozzles and corresponding seven orifices 105 located at the front end.

108 is a supply chamber cover which forms, in cooperation with said cover plate 107, a common supply chamber 118 for supplying the liquid recording medium to said seven nozzles, said supply chamber 118 being provided with a pipe 109 for receiving supply of the liquid from an external liquid reservoir (not shown).

On the surface of rear end of base plate 106 there are provided, for connection with external electric means, lead contacts connected to a common electrode 110 and selection electrodes 111 of electrothermal transducers respectively mounted on said seven nozzles.

On the rear surface of base plate 106 there is provided a heat sink 112 for improving the response of electrothermal transducers, said heat sink being however dispensable in case the base plate 106 itself performs the above-mentioned function.

Figure 12 shows the recording head 104 of Figure 11 in an elevation view for particularly clarifying the arrangement of emitting orifices 105.

In the recording head 104, the orifices 105, though being illustrated in an approximately semi-circular shape, may also be of other shapes such as rectangular, or circular shape etc, suitably selected according the convenience of mechanical working.

The recording head 104 of the present invention allows to easily obtain a high-density multi-orificed structure as the structural simplicity thereof permits the use of ultra-microworking technology for minimizing the dimension of orifices 105 and spacings therebetween. Consequently it is easily possible to achieve a high resolution in the recording head and accordingly in the recorded image. As an example a resolution of 10 line pairs/mm is achieved by certain heads thus far prepared in this manner.

Figure 13 is a partial cross-sectional view along the line X1—Y1 in Figure 11 showing the internal structure of the recording head 104, particularly the structure of electrothermal transducer 113 and the liquid flow path therein.

The electrothermal transducer 113 is essentially composed of a heat-generating resistor 115 provided on a heat-accumulating layer 114 eventually provided for example by evaporation or plating on a base plate 106, and a common electrode 110 and a selecting electrode 111 both for supplying current to said resistor 115, said transducer being eventually provided thereon, if necessary, with a protective insulating layer 116 for preventing electric leak between the electrodes by the liquid and/or preventing staining of electrodes 110, 111 and resistor 115 by the liquid 117 and/or preventing oxidation of said resistor 115.

A supply chamber is formed as a space enclosed by a cover plate 107, chamber lid 108 and the base plate 106 and is in communication with each of seven nozzles formed by the base plate 106 and cover plate member 107, and further in communication with a pipe 109 through which the liquid supplied from outside is introduced into each of said nozzles. Also said supply chamber 118 should be designed with such a volume and a shape as to have a sufficient impedance, when a backward wave developed in the thermal chamber portion Δl in each nozzle cannot be dissipated within each nozzle and is transmitted to said supply chamber, to such backward wave to prevent mutual interference in the emissions from different nozzles.

Although said supply chamber 118 is composed of a space enclosed by the cover plate 107, chamber lid 108 and base plate 106 in the illustrated recording head 104, it may also be composed of a space surrounded by the chamber lid 108 and base plate 106 or of a space enclosed solely by said chamber lid 108.

In consideration, however, of the ease of working and assembly as well as the desired working precision, most preferred is the recording head 104 of the structure shown in Figure 11.

Figure 14 is a partial cross-sectional view along the line X2—Y2 in Figure 13 showing the planar structure of electrothermal transducers 113 used in the recording head 104.

Seven electrothermal transducers (113-1, 113-2, ..., 113-7) of a determined size and shape are provided on the base plate 106 respectively corresponding to seven nozzles, and a common electrode 110 is provided in electrical contact, in a part thereof, with an end at the orifice side of each of said seven resistors (115-1, 115-2, ..., 115-7) and with a contact lead portion surrounding seven parallel nozzles to allow electrical connection to an external circuit.

Also said seven resistors 115 are respectively provided with selecting electrodes (111-1, 111-2, ..., 111-7) along the flow paths of liquid.

The electrothermal transducers 113 which are provided on the base plate 106 in the illustrated recording head 104 may instead be provided on the cover member 107. Further, the grooves for forming the nozzles, which are provided in the cover member 107 in case of the illustrated structure, may instead be provided on the base plate 106, or provided on both of the cover 107 and the base

plate 106. When said grooves are provided on the base plate 106, the electrothermal transducers are preferably provided on the cover member 107 for the ease of preparation.

Referring to Figure 13, upon application of a pulse voltage between the electrodes 110 and 111, the resistor 115 initiates to generate heat, which is transmitted, through the protective layer 116 to the liquid contained in the thermal chamber portion Δ*l*. Upon receipt of said thermal energy the liquid at least reaches a temperature of internal gasification to generate bubbles in the thermal chamber portion Δ*l*. The volume increase resulting from said bubble formation applies a pressure to the liquid located closer to the orifice larger than the surface tension thereof at the orifice 105 to cause projection of droplets from the orifice 105. Simultaneously with the trailing down of the pulse voltage the resistor 115 terminates heat generation, so that the generated bubbles contract in size and vanish, and the emitted liquid is replenished by the newly supplied liquid. The formation and vanishing of bubbles are repeated in the chamber portion Δ*l* in response to successive application of pulse voltages between the electrodes 110 and 111 in the above-mentioned manner, thereby achieving projection of droplets from the orifice 105 corresponding to each pulse voltage application.

The protective layer 116 need not necessarily be insulating if the liquid 117 has an electric resistance significantly higher than that of the resistor 115 and thus does not cause electric leak between the electrodes 110 and 111 even in the eventual presence of said liquid therebetween, and is only required to satisfy other requirements among which most important is a property to maximize effective transmission of heat generated by the resistor 115 to the thermal chamber portion Δ*l*.

The material and thickness of said protective layer are so selected as to obtain properties responding to the foregoing requirement in addition to the above-explained property:

The useful examples of material for forming the protective layer 116 are silicon oxide, magnesium oxide, aluminum oxide, tantalum oxide, zirconium oxide etc, which can be deposited into a form of layer by means of example of electron beam evaporation or sputtering. Also said layer may be of a multiple layer structure having two or more layers. The thickness of layer is determined by various factors such as the material to be used, material, shape and dimension of the resistor 115, material of the base plate 106, thermal response from the resistor 115 to the liquid contained in the thermal chamber portion Δ*l*, prevention of oxidation required for the resistor 115, prevention of liquid permeation required for the resistor 115, electric insulation etc, and is usually selected within a range from 0.01 to 10 μ, preferably from 0.1 to 5 μ, and most preferably from 0.1 to 3 μ.

For the purpose of more effectively applying the thermal energy developed by the resistor to the liquid contained in the thermal chamber portion Δ*l* thereby improving the response, also enabling stable continuous projection of liquid for a prolonged period and achieving a sufficient compliance of the liquid projection even when the resistor 115 is driven with a high frequency, the heat-accumulating layer 114 and the base plate 106 are preferably structured in the following manner to further improve the performance of heat-generating resistor 115.

Figure 15 shows a general relationship between the difference ΔT between the surface temperature TR of resistor and the boiling point Tb of liquid represented in the abscissa and the thermal energy ET transmitted from the resistor to the liquid represented in the ordinate. As clearly shown in this chart, the energy transmission to the liquid is conducted efficiently in a temperature region around point D where the surface temperature TR of resistor is several tens of degrees higher than the boiling point Tb of liquid, while it becomes less efficient in a region around point E where said surface temperature is approximately 100°C higher than the boiling temperature Tb of liquid since rapid bubble formation between the resistor and the liquid hinders the heat transmission therebetween.

Thus, in order to improve the projecting efficiency, response and frequency characteristics it is desirable to minimize the heating period in a region represented by the curve A-B-C-D-E for achieving instantaneous and efficient energy transmission to the liquid present close to the surface of resistor and for avoiding transmission to the liquid present in other areas, and to resume the original temperature instantaneously as soon as the heat generation is terminated.

Based on the foregoing considerations the heat-accumulating layer 114 should perform a function of preventing heat diffusion to the base plate 106 when the heat generated by the resistor 115 is required thereby achieving effective heat transmission to the liquid contained in the thermal chamber portion Δ*l*, and of causing heat diffusion to the base plate 106 when said heat is not required, and the material and thickness of said layer are to be determined in consideration of the above-mentioned requirement. Examples of material useful for forming said heat-accumulating layer 114 are silicon oxide, zirconium oxide, tantalum oxide, magnesium oxide, aluminum oxide etc, which can be deposited in a form of layer by means for example of electron beam evaporation or sputtering.

The layer thickness is suitably determined according to the material to be used, materials to be used for the base plate 106 and resistor 115 etc so as to achieve the above-mentioned function, and is usually selected within a range from 0.01 to 50 μ, preferably from 0.1 to 30 μ and most preferably from 0.5 to 10 μ.

The base plate 106 is composed of a heat-conductive material, such as a metal, for dissipating unnecessary portion of heat generated by the resistor 115. Examples of metal usable for this purpose are Al, Cu and stainless steel among which most preferred is aluminum.

The cover member 107 and the supply chamber lid 108 may be composed of almost any material

as long as it is not or substantially not thermally deformed at the preparation or during the use of recording head and it accepts easily precision working to achieve a desired accuracy of surfaces and to realize smooth flow of liquid in the paths obtained by such working.

Representative examples of such material are ceramics, glass, metals, plastics etc, among which particularly preferred are glass and plastics for the ease of working, and the appropriate thermal resistance, thermal expansion coefficient and thermal conductivity they have.

As already explained in connection with Figure 6, the external surface around the orifices is preferably subjected to a water-repellent or oil-repellent treatment, respectively when the liquid is aqueous or non-aqueous, in order to prevent that said surface becomes wetted by the liquid leaking from the orifice.

In the following given is a preferred example of preparation of recording head 104 shown in Figure 11.

An Al_2O_3 base plate 106 of a thickness of 0.6 mm was subjected to sputtering of SiO_2 to obtain a heat-accumulating layer of a thickness of 3 μ, then to sputtering of ZrB_2 of a thickness of 800 Å as the heat-generating resistor and of Al of a thickness of 5000 Å as the electrodes, followed by selective photoetching to form seven resistors of each 400 Ω in resistance and 50 μ wide and 300 μ in dimension arranged at a pitch of 250 μ, and further subjected to sputtering of SiO_2 into a thickness of 1 μ as the insulating protective layer 116 thereby completing the electrothermal transducers.

Successively a glass cover plate on which grooves of 60 μ wide and 60 μ deep were formed at a pitch of 250 μ by a microcutter and a glass chamber plate 108 were adhered on said base plate 106 on which the electrothermal transducers were prepared in the above-explained manner, and an aluminum heat sink 112 was adhered on a surface opposite to the above-mentioned adhered surface.

In the present example, as the orifice 105 obtained was satisfactorily small, there was conducted no other particular step such as to attach a separate member on the front end of nozzle for forming an orifice of desired diameter. However it is also possible to mount an orifice plate having an orifice of a desired shape to the front end of the nozzle in case the nozzle has a larger diameter or it is desirable to improve the emission characteristics or to modify the size of droplets to be emitted.

Now there will be given an explanation on the control mechanism for use in recording with a recording apparatus incorporating a recording head 104 shown in Figure 11, while making reference to Figures 17 to 24.

Figures 17 to 20 show an embodiment of the control mechanism adapted for use in case of simultaneously controlling the electrothermal transducers (113-1, 113-2, ..., 113-7* according to external signals thereby causing simultaneous droplet emission from the orifices (105-1, 105-2, ..., 105-7) corresponding to said signals.

Referring to Figure 7 showing a block diagram of the entire apparatus, input signals obtained by keyboard operation of a computer 122 supplied from an interface circuit 123 to a data generator 124, which selects desired characters from a character generator 125 and arranges the data signals into a form suitable for printing. Thus arranged data are temporarily stored in a buffer circuit 126 and supplied in succession to drive circuits 127 to drive corresponding transducers (113-1, 113-2, ..., 113-7) for causing droplet emission. Also there is provided a control circuit 128 for controlling the timings of input and output of other circuits and also for releasing instruction signals therefor.

Figure 18 is a timing chart showing the function of the buffer circuit 126 shown in Figure 17, which receives data signals S102 arranged in the data generator 124 in synchronization with character clock signals S101 generated in the character generator and releases output signals to the drive circuits 127 in different timings. Although said input and output functions are performed by one buffer circuit in case of the embodiment shown in Figure 17, it is also possible to perform these functions with plural buffer circuits, namely by so-called double buffer control in which a buffer circuit performs input function while the other buffer circuit performs output function and in the next timing the functions of said buffer circuits are interchanged. In such double buffer control it is also possible to cause continuous projection of droplets.

In this manner seven transducers (113-1, 113-2, ..., 113-7) are simultaneously controlled for example accordingly to a timing chart of droplet emission as shown in Figure 19, thereby creating a print as shown in Figure 20 by means of droplets projected from seven orifices. The signals S111—S117 respectivly represent those applied to said seven transducers 113-1, 113-2, ..., 113-7.

Figures 21 to 24 show an embodiment of the control mechanism for controlling the electrothermal transducers in succession thereby causing droplet emission from the orifices in succession.

Referring to Figure 21 showing a block diagram of the entire apparatus, external input signals S130 are supplied through an interface circuit 129 and rearranged in a data generator 130 into a form suitable for printing. In case of printing for each column as shown in Figure 21, the data for each column are read from a character generator 131 and temporarily stored in a column buffer circuit 132. Simultaneously with the readout of column data from the character generator 131 and input thereof into a column buffer circuit 132-2, and another column buffer circuit 132-1 releases another data to a drive circuit 133. A control circuit 134 is provided for releasing signals for selecting the buffer circuits

132, for controlling the input and output of other circuits and for instructing the functions of other circuits.

Figure 22 is a timing chart showing the function of said buffer circuits 132 and of the drive circuit 133 of which column data output signals are controlled by a gate circuit 135 so as to successively drive the transducers 113-1, 113-2, ..., 113-7. In Figure 22 there are shown character clock signals S141, input signals S142 to column buffer circuit 132-1, input signals S143 to column buffer circuit 132-2, output signals S144 from column buffer circuit 132-1 and output signals S145 from column buffer circuit 132-2. As the result the droplets are projected from seven orifices in succession according for example to the timing shown in Figure 23 to obtain a printed character as shown in Figure 24 wherein S151 to S157 respectively stand for signals applied to the transducers 113-1, 113-2, ..., 113-7.

Although the foregoing explanation is limited to control on character printing, the control in case of reproducing an image is also possible in a similar manner. Also the foregoing explanation is made in connection with the use of a recording head having seven orifices, but a similar control is applicable in case of using a full-line multi-orificed recording head.

In the following shown is an example of recording with a recording head having seven orifices as shown in Figure 11 and prepared in the manner as explained in the foregoing.

The above-mentioned recording head was incorporated in a recording apparatus provided with a liquid projection control circuit, and recording was conducted by applying pulse voltages to seven electrothermal transducers according to image signals while supplying the liquid recording medium through the pipe 109 under a pressure of a magnitude not causing emission of the liquid from the orifice 105 when the resistor 115 does not generate heat. In this manner a clear image could be obtained under the conditions shown in the following Table 1:

Table 1

Drive voltage	20 V	
Pulse width	100 μsec	
Frequency	1 KHz	
Record-receiving member	Bond Paper (Seven Star A 28.5 Kg; Hokuetsu Paper)	
Liquid recording medium	Water	68 gr
	Ethylene Glycol	30 gr
	Direct Fast Black (Sumitomo Chemical Ind.)	2 gr

As another example, recording was conducted with a similar apparatus by applying continuously repeating pulse voltages of 20 KHz to seven electrothermal transducers while supplying the liquid recording medium to the recording head 104 under a pressure of a magnitude causing overflow of the liquid from the orifice 105 when the resistor 115 was not generating heat. In this manner it was confirmed that droplets of a number corresponding to the applied frequency could be emitted stably with a uniform diameter.

From the foregoing examples it is confirmed that the recording head constituting a principal portion of the present invention is effectively applicable for generating continuous emission of droplets at a high frequency.

Other Embodiments of the Present Invention

Example A

Figure 25 schematically shows an another embodiment of the apparatus of the present invention, in which a nozzle 137 is arranged in contact, at the front end thereof, with a heat-generating portion of an electrothermal transducer 138 and is connected at the other end thereof to a pump 139 for supplying a liquid recording medium into said nozzle 137. 140 is a pipe for supplying said liquid from a reservoir (not shown) to said pump 139. The electrothermal transducer 138 is provided, along the axis of nozzle 137, with six independent heat-generating resistors (not visible in the drawing as they are provided under the nozzle 137) in order to modify the position of application of thermal energy, said resistors being provided with selecting electrodes 141 (A1, A2, A3, A4, A5 and A6) and a common electrode 142. 143 is a drum for rotating a record-receiving member mounted thereon, of which rotating speed is suitably synchronizable with the scanning speed of nozzle 137.

Recording was conducted with the above-explained apparatus, utilizing black 16-1000 (A. B. Dick) as the liquid recording medium and under the conditions shown in Table 2.

Also Table 3 shows the diameter of spot obtained on the record-receiving medium in such recording by activating each of said resistors in the electrothermal transducer 138. These results indicate that the spot diameter of the liquid obtained on the record-receiving medium can be varied by changing the position of position of thermal energy on the nozzle 137.

Thus an image recording conducted in such a manner that either one of six heat-generating

resistors is activated according to the input level of recording information signals provides a clear image of an excellent quality rich in gradation.

Table 2

Orifice diameter	100 μm
Nozzle scanning pitch	100 μ
Drum peripheral speed	10 cm/sec
Signals to resistors	pulses of 15 V, 200 μsec
Drum-orifice distance	2 cm
Record-receiving member	Ordinary paper

Table 3

Resistor	A1	A2	A3	A4	A5	A6
Spot diameter (μm)	200±10	180±12	160±12	140±12	120±10	100±10

Example B

Figure 26 schematically shows an another embodiment of the apparatus of the present invention also providing a clear image printing, in which a recording head 144 is composed of a nozzle 146 having an orifice for emitting the liquid recording medium and an electrothermal transducer 145 provided surrounding a part of said nozzle 146. Said recording head 144 is connected, through a pipe joint 147, to a pump 148 for supplying the liquid recording medium to said nozzle 146, said medium being supplied to said pump 148 as shown by the arrow in the drawing.

There are also shown a charging electrode 149 for charging, according to the recording information signals, the droplets formed upon emission from the orifice, deflecting electrodes 150a, 150b for deflecting the direction of flight of thus charged droplets a gutter 151 for recovering droplets not required for recording, and a record-receiving member 152.

Recording with the above-explained apparatus was conducted with Casio C.J.P. Ink (Casio Co.) and under the conditions shown in Table 4.

Table 4

Orifice diameter	50 μm
Signals to transducer 107	Constant pulses of 15V, 200 μsec, 2 KHz
Charging electrode voltage	0—200 V
Voltage between deflecting electrodes	1 KV
Orifice-charging electrode distance	4 mm

Example C

Figure 27 schematically shows, in a perspective view, a still another embodiment of the apparatus of the present invention, wherein a laser beam generated by a laser oscillator 153 is guided into an acousto-optical modulator 154 and is intensity modulated therein according to the input information signals. Thus modulated laser beam is deflected by a mirror 155 and is guided to a beam expander 156 for increasing the beam diameter while retaining the parallel beam state. The beam with thus increased diameter is then guided to a polygonal mirror 157 mounted on the shaft of a hysteresis synchronous motor 158 for rotation at a constant speed. The horizontally sweeping beam obtained from said polygonal mirror is focused, by means of an f-θ lens and via a mirror 160, onto a determined position on each of nozzles 162 aligned at the front end of a multi-orificed recording head 161. Thus focused laser beam provides thermal energy to the liquid recording medium contained in the thermal chamber portion of each nozzle thereby causing projection of droplets of said liquid from the nozzle orifices for achieving recording on a record-receiving member 163. Each of the nozzles in said recording head 161 receives supply of the liquid from a pipe 164. In the recording head 161 of the present example, the length of nozzles is 20 cm, the number of nozzles is 4/mm and the diameter of orifice is ca. 40 μ. The recording conditions employed are shown in Table 5, and the preparation of liquid recording medium is shown in the following.

Table 5

Laser	YAG laser, 40 W
Laser scanning speed	25 lines/sec
Record-receiving member	Ordinary paper; 10 cm/sec

Preparation of liquid recording medium: 1 part by weight of an alcohol-soluble nigrosin dye (spirit Black SB; Orient Chemical) is dissolved in 4 parts by weight of ethylene glycol, and 60 parts by weight of thus obtained solution is poured under agitation into 94 parts by weight of water containing 0.1 w%

of Dioxin (trade name). The resulting solution is filtered twice through a Millipore filter of an average pore diameter of 10 μ to obtain an aqueous recording medium.

Example D

In this example image recording is conducted with a multi-orificed recording head 165 schematically shown in a partial perspective view in Figure 28, wherein said recording head 165 comprises a number of nozzles 166 each having an orifice for emitting the liquid recording medium, said nozzles 166 being maintained in parallel state by support members 167, 168, 169 and 170 to form a nozzle array 171 and being connected to a common liquid supply chamber 172, to which the liquid is supplied through a pipe 173 as shown by the arrow in the drawing.

Referring to Figure 29 showing a partial cross-section along the dotted line X″—Y″ in Figure 28, each nozzle 166 is provided on the surface thereof with an independent electrothermal transducer 174 which is composed of a heat-generating member 175 provided on the surface of nozzle 166, electrodes 176 and 177 provided on both ends of said heat-generating member 175, a lead electrode common to all the nozzles and connected to said electrode 176, a selecting lead electrode 179 connected to said electrode 177, and an anti-oxidation layer 180.

Also there are shown insulating sheets 181, 182, and rubber cushions 183, 185, 186 for preventing mechanical breakage of nozzles.

Upon receipt of signals corresponding to information to be recorded, the heat-generating member 175 of electrothermal transducer 174 develops heat, which causes a state change in the liquid recording medium contained in the thermal chamber portion of nozzles 166 thereby causing projection of droplets of said liquid from the orifices of nozzles 166 for deposition onto a record-receiving member 191.

The apparatus of the present example provided under the conditions shown in Table 6, an extremely clear image of a satisfactory quality with an average spot diameter of ca. 60 μ.

Table 6

Orifice diameter	50 μm
Pitch of nozzles	4/mm
Speed of record-receiving member	50 cm/sec
Signals to transducers	Pulses of 15 V, 200 sec
Orifice-member distance	2 cm
Record-receiving member	Ordinary paper
Liquid recording medium	Casio C.J.P. Ink

Also recorded images of an excellent quality can be obtained on ordinary paper with the liquid recording medii of the following compositions (No. 5—No. 9);

No. 5	Calcovd Black SR (American Cyanamid)	40 wt.%
	Diethylene glycol	7.0 wt.%
	Dioxine (Trade name)	0.1 wt.%
	Water	88.9 wt.%
No. 6	N-methyl-2-pyrrolidone containing	20 wt.% of
	an alcohol-soluble nigrosin dye	9 wt.%
	Polyethylene glycol	16 wt.%
	Water	75 wt.%
No. 7	Kayaku Direct Blue BB (Nippon Kayaku)	4 wt.%
	Polyoxyethylene monopalmitate	1 wt.%
	Polyethylene glycol	8.0 wt.%
	Dioxin (trade name)	0.1 wt.%
	Water	86.9 wt.%
No. 8	Kayaset red 026 (Nippon Kayaku)	5 wt.%
	Polyoxyethylene monopalmitate	1 wt.%
	Polyethylene glycol	5 wt.%
	Water	89 wt.%
No. 9	C.I. Direct Black 40 (Sumitomo Chemical)	2 wt.%
	Polyvinyl alcohol	1 wt.%
	Isopropyl alcohol	3 wt.%
	Water	94 wt.%

Recording Medium

The liquid recording medium to be employed in the present invention is required to be provided with, in addition to chemical and physical stability required for the recording liquids used in ordinary recording methods, other properties such as satisfactory response, fidelity and fiber-forming ability, absence of solidification in the nozzle, flowability in the nozzle at a speed corresponding to the recording speed, rapid fixation on the record-receiving member, sufficient record density, sufficient pot life etc.

In the present invention there can be employed any liquid recording medium as long as the above-mentioned requirements are satisfied, and most of the recording liquids conventionally used in the field of recording related to the present invention are effectively usable for this purpose.

Such liquid recording medium is composed of a carrier liquid, a recording material for forming the recorded image and additive materials eventually added for achieving desired properties, and can be classified into the categories of aqueous, non-aqueous, soluble, electro-conductive and insulating.

The carrier liquids are classified into aqueous solvents and non-aqueous solvents.

Most of the ordinarily known non-aqueous solvents are conveniently usable in the present invention. Examples of such non-aqueous solvents are alkylalcohols having 1 to 10 carbon atoms such as methyl alcohol, ethyl alcohol, n-propyl alcohol, iso-propyl alcohol, n-butyl alcohol, sec-butyl alcohol, tert-butyl alcohol, iso-butyl alcohol, amyl alcohol, hexyl alcohol, heptyl alcohol, octyl alcohol, nonylalcohol, decyl alcohol etc; hydrocarbon solvents such as hexane, octane, cyclopentane, benzene, toluene, xylol etc; halogenated hydrocarbon solvents such as carbon tetrachloride, trichloroethylene, tetrachloroethane, dichlorobenzene etc; ether solvents such as ethylether, butylether, ethylene glycol diethylethyer, ethylene glycol monoethylether etc; ketone solvents such as acetone, methylethylketone, methylpropylketone, methylamylketone, cyclohexanone etc; ester solvents such as ethyl formate, methyl acetate, propyl acetate, phenyl acetate, ethylene glycol monoethylether acetate etc; alcohol solvents such as diacetone alcohol etc; and high-boiling hydrocarbon solvents.

The above-mentioned carrier liquids are suitably selected in consideration of the affinity with the recording material and other additives to be employed and in order to satisfy the foregoing requirements, and may also be used as a mixture of two or more solvents or a mixture with water, if necessary and within a limit that a desirable recording medium is obtainable.

Among the carrier liquids mentioned above, preferred are water and water-alcohol mixtures in consideration of ecology, availability and ease of preparation.

The recording material has to be selected in relation to the above-mentioned carrier liquid and to the additive materials so as to prevent sedimentation or coagulation in the nozzles and reservoir and clogging of pipes and orifices after a prolonged standing. In the present invention preferred, therefore, is the use of recording materials soluble in the carrier liquid, but those not or difficultly soluble in the carrier liquid are also usable in the present invention as long as the size of dispersed particles is satisfactorily small.

The recording material to be employed in the present invention is to be suitably selected according to the record-receiving member and other recording conditions to be used in the recording, and various conventionally known dyes and pigments are effectively usable for this purpose.

The dyes effectively employable in the present invention are those capable of satisfying the foregoing requirements for the prepared recording medium and include water-soluble dyes such as direct dyes, basic dyes, acid dyes, solubilised vat dyes, acid mordant dyes and mordant dyes; and water-insoluble dyes such as sulpher dyes, vat dyes, spirit dyes, oil dyes and disperse dyes; and other dyes such as stylene dyes, naphthol dyes, reactive dyes, chrome dyes, 1:2 complex dyes, 1:1 complex dyes, azoic dyes, cationic dyes etc.

Preferred examples of such dyes are Resolin Brilliant Blue PRL, Resolin Yellow PGG, Resolin Pink PRR, Resolin Green PB (above available from Farbefabriken Bayer A.G.); Sumikaron Blue S-BG, Sumikaron Red E-EBL, Sumikaron Yellow E-4GL, Sumikaron Brilliant Blue S-BL (above from Sumitomo Chemical Co., Ltd.); Dianix Yellow HG-SE, Dianix Red BN-SE (above from Mitsubishi Chemical Industries Limited); Kayalon Polyester Light Flavin 4GL, Kayalon Polyester Blue 3R-SF, Kayalon Polyester Yellow YL-SE, Kayaset Turquoise Blue 776, Kayaset Yellow 902, Kayaset Red 026, Procion Red H-2B, Procion Blue H3R (above from Nippon Kayaku); Levafix Golden Yellow P-R, Levafix Brilliant Red P-B, Levafix Brilliant Orange P-GR (above from Farbenfabriken Bayer A.G.); Sumifix Yellow GRS, Sumifix Red B, Sumifix Brilliant Red BS, Sumifix Brilliant Blue RB, Direct Black 40 (above from Sumitomo Chemical); Diamira Brown 3G, Diamira Yellow G, Diamira Blue 3R, Diamira Brilliant Blue B, Diamira Brilliant Red BB (above from Mitsubishi Chemical Industries); Remazol Red B, Remazol Blue 3R, Remazol Yellow GNL, Remazol Brilliant Green 6B (above from Farbewerke Hoechst A.G.); Cibracron Brilliant Yellow, Cibracron Brilliant Red 4GE (above from Ciba Geigy); Indigo, Direct Deep Black E-Ex, Diamin Black BH, Congo Red, Sirius Black, Orange II, Amid Black 10B, Orange RO, Metanil Yellow, Victoria Scarlet, Nigrosine, Diamond Black PBB (above from I.G. Farbenindustrie A.G.); Diacid Blue 3G, Diacid Fast Green GW, Diacid Milling Navy Blue R, Indanthrene (above Mitsubishi Chemical Industries); Zabon dye (from BASF); Oleosol dyes (from CIBA); Lanasyn dyes (Mitsubishi Chemical Industries); Diacryl Orange RL-E, Diacryl Brilliant Blue 2B-E, Diacryl Turquoise Blue BG-E (above from Mitsubishi Chemical Industries) etc.

These dyes are used in a form of solution or dispersion in a carrier liquid suitably selected according to the purpose.

The pigments effectively employable in the present invention include various inorganic and organic pigments, and preferred are those of an elevated infrared absorbing efficiency in case infrared light is used as the source of thermal energy. Examples of such inorganic pigment include cadmium sulfide, sulfur, selenium, zinc sulfide, cadmium sulfoselenide, chrome yellow, zinc chromate, molybdenum red, guignet's green, titanium dioxide, zinc oxide, red iron oxide, green chromium oxide, red lead, cobalt oxide, barium titanate, titanium yellow, black iron oxide, iron blue, litharge, cadmium red, silver sulfide, lead sulfide, barium sulfate, ultramarine, calcium carbonate, magnesium carbonate, white lead, cobalt violet, cobalt blue, emerald green, carbon black etc.

Organic pigments are mostly classified as and thus overlap organic dyes, but preferred examples of such organic pigments effectively usable in the present invention are as follows:

a) Insoluble azo-pigments (naphthols):
Brilliant Carmine BS, Lake Carmine FB, Brilliant Fast Scarlet, Lake Red 4R, Para red, Permanent Red R, Fast Red FGR, Lake Bordeaux 5B, Bar Million No. 1, Bar Million No. 2, Toluidine Maroon;

b) Insoluble azo-pigments (anilids):
Diazo Yellow, Fast Yellow G, Fast Yellow 100, Diazo Orange, Vulcan Orange, Ryrazolon Red;

c) Soluble azo-pigments:
Lake Orange, Brilliant Carmine 3B, Brilliant Carmine 6B, Brilliant Scarlet G, Lake Red C, Lake Red D, Lake Red R, Watchung Red, Lake Bordeaux 10B, Bon Maroon L. Bon Maroon M;

d) Phthalocyanine pigments:
Phthalocyanine Blue, Fast Sky Blue, Phthalocyanine Green;

e) Lake pigments:
Yellow Lake, Eosine Lake, Rose Lake, Violet Lake, Blue Lake, Green Lake, Sepia Lake;

f) Mordant dyes:
Alizatine Lake, Madder Carmine;

g) Vat dyes:
Indanthrene, Fast Blue Lake (GGS);

h) Basic dye Lakes:
Rhodamine Lake, Malachite Green Lake;

i) Acid dye Lakes:
Fast Sky Blue, Quinoline Yellow Lake, quinacridone pigments, dioxazine pigments.

The ratio of the above-mentioned carrier liquid and recording material to be employed in the present invention is determined in consideration of eventual nozzle clogging, eventual drying of recording liquid in the nozzle, clogging on the record-receiving member, drying speed thereon etc, and is generally selected within a range, with respect to 100 parts by weight of carrier liquid, of 1 to 50 parts by weight of recording material, preferably 3 to 30 parts by weight, and most preferably 5 to 10 parts by weight of recording material.

In case the liquid recording medium consists of a dispersion wherein the particles of recording material are dispersed in the carrier liquid, the particle size of said dispersed recording material is suitably determined in consideration of the specy of recording material; recording conditions, internal diameter of nozzle, diameter of orifice, specy of record-receiving member etc. However an excessively large particle size is not desirable as it may result in sedimentation of recording material during storage leading to uneven concentration, nozzle clogging or uneven density in the recorded image.

In order to avoid such troubles the particle size of recording material in a dispersed recording medium to be employed in the present invention is generally selected within a range from 0.0001 to 30 μ, preferably from 0.0001 to 20 μ and most preferably from 0.0001 to 8 μ. Besides the extent of particle size distribution of such dispersed recording material is to be as narrow as possible, and is generally selected within a range of $D\pm3\ \mu$ preferably within a range of $D\pm1.5\ \mu$ wherein D stands for the average particle size.

The liquid recording medium for use in the present invention is essentially composed of the carrier liquid and the recording materials as explained in the foregoing, but it may further contain other additive materials for realizing or improving the aforementioned properties required for recording.

Such additive materials include viscosity regulating agents, surface tension regulating agents, pH regulating agent, resistivity regulating agent, wetting agents, infrared-absorbing heat-generating agents etc.

Such viscosity regulating agent and surface tension regulating agent are added principally for achieving a flowability in the nozzle at a speed sufficiently responding to the recording speed, for preventing dropping of recording medium from the orifice of nozzle to the external surface thereof, and for blotting (widening of spot) on the record-receiving member.

For these purposes any known viscosity regulating agent or surface tension regulating agent is applicable as long as it does not provide undesirable effect to the carrier liquid and recording material.

Examples of such viscosity regulating agent are polyvinyl alchol, hydroxypropylcellulose carboxymethyl cellulose, hydroxyethyl cellulose, methyl cellulose, water-soluble acrylic resins, polyvinylpyrrolidone, gum Arabic, starch etc.

The surface tension regulating agents effectively usable in the present invention include anionic, cationic and nonionic surface active agents, such as polyethyleneglycolether sulfate, ester salt etc as the anionic compound, poly-2-vinylpyridine derivatives, poly-4-vinylpyridine derivatives etc as the cationic compound, and polyoxyethylenealkylether, polyoxyethylenealkylphenylether, polyoxyethylenealkyl esters, polyoxyethylenesorbitan alkylester, polyoxyethylene alkylamines etc as the nonionic compound. In addition to the above-mentioned surface active agents, there can be effectively employed other materials such as amine acids such as diethanolamine, propanolamine, morphole etc, basic compounds such as ammonium hydroxide, sodium hydroxide etc, and substituted pyrrolidones such as N-methyl-2-pyrrolidone etc.

These surface tension regulating agents may also be employed as a mixture of two or more compounds so as to obtain a desired surface tension in the prepared recording medium and within a limit that they do not undesirably affect each other or affect other constituents.

The amount of said surface tension regulating agents is determined suitably according to the species thereof, species of other constituents and desired recording characteristics, and is generally selected, with respect to 1 part by weight of recording medium, in a range from 0.0001 to 0.1 parts by weight, preferably from 0.001 to 0.01 parts by weight.

The pH regulating agent is added in a suitable amount to achieve a determined pH value thereby improving the chemical stability of prepared recording medium, thus avoiding changes in physical properties and avoiding sedimentation or coagulation of recording material or other components during a prolonged storage.

As the pH regulating agent adapted for use in the present invention, there can be employed almost any materials capable of achieving the desired pH value without giving undesirable effects to the prepared liquid recording medium.

Examples of such pH regulating agent are lower alkanolamine, monovalent hydroxides such as alkali metal hydroxide, ammonium hydroxide etc.

Such pH regulating agent is added in an amount required for realizing a desired pH value in the prepared recording medium.

In case the recording is achieved by charging the droplets of liquid recording medium, the resistivity thereof is an important factor for determining the charging characteristics. In order that the droplets can be charged for achieving a satisfactory recording, the liquid recording medium is to be provided with a resistivity generally within a range of 10^{-3} to $10^{11}\Omega$cm.

Examples of resistivity regulating agent to be added in a suitable amount to achieve the resistivity as explained above in the liquid recording medium are inorganic salts such as ammonium chloride, sodium chloride, potassium chloride etc, water-soluble amines such as triethanolamine etc, and quaternary ammonium salts.

In case of recording wherein the droplets are not charged, the resistivity of recording medium need not be controlled.

As the wetting agent adapted for use in the present invention there can be employed various materials known in the technical field related to the present invention, among which preferred are those thermally stable. Examples of such wetting agent are polyalkylene glycols such as polyethylene glycol, polypropylene glycol etc; alkylene glycols containing 2 to 6 carbon atoms such as ethylene glycol, propylene glycol, butylene glycol, hexylene glycol etc; lower alkyl ethers of diethylene glycol such as ethyleneglycol methylether, diethyleneglycol methylether, diethyleneglycol ethylether etc; glycerin; lower alkoxy triglycols such as methoxy triglycol, ethoxy triglycol etc; N-vinyl-2-pyrrolidone oligomers etc.

Such wetting agents are added in an amount required for achieving desired properties in the recording medium, and is generally added within a range from 0.1 to 10 wt.%, preferably 0.1 to 8 wt.% and most preferably 0.2 to 7 wt.% with respect to the entire weight of the liquid recording medium.

The above-mentioned wetting agents may be used, in addition to single use, as a mixture of two or more compounds as long as they do not undesirably affect each other.

In addition to the foregoing additive materials the liquid recording medium of the present invention may further contain resinous polymers such as alkyd resin, acrylic resin, acrylamide resin, polyvinyl alcohol, polyvinylpyrrolidone etc in order to improve the film forming property and coating strength of the recording medium when it is deposited on the record-receiving member.

In case of using laser energy, particularly infrared laser energy, it is desirable to add an infrared-absorbing heat-generating material into the liquid recording medium in order to improve the effect of laser energy. Such infrared-absorbing materials are mostly in the family of the aforementioned recording materials and are preferably dyes or pigments showing a strong infrared absorption. Examples of such dyes are water-soluble nigrosin dyes, denatured water-soluble nigrosin dyes, alcohol-soluble nigrosin dyes which can be rendered water-soluble etc, while the examples of such pigments include inorganic pigments such as carbon black, ultramarine blue, cadmium yellow, red iron oxide, chrome yellow etc, and organic pigments such as azo pigments, triphenylmethane pigments, quinoline pigments, anthraquinone pigments, phthalocyanine pigments etc.

In the present invention the amount of such infrared absorbing heat-generating material, in case

it is used in addition to the recording material, is generally selected within a range of 0.01 to 10 wt.%, preferably 0.1 to 5 wt.% with respect to the entire weight of the liquid recording medium.

Said amount should be maintained as a minimum necessary level particularly when such infrared-absorbing material is insoluble in the carrier liquid, as it may result in sedimentation, coagulation or nozzle clogging for example during the storage of liquid recording medium, though the extent of such phenomena is dependent on the particle size in the dispersion.

As explained in the foregoing, the liquid recording medium to be employed in the present invention is to be prepared in such a manner that the values of specific heat, thermal expansion coefficient, thermal conductivity, viscosity, surface tension, pH and resistivity, in case the droplets are charged at recording, are situated within the respectively defined ranges in order to achieve the recording characteristics described in the foregoing.

In fact these properties are closely related to the stability of fiber-forming phenomenon, response and fidelity to the effect of thermal energy, image density, chemical stability, fluidity in the nozzle etc. so that in the present invention it is necessary to pay sufficient attention to these factors at the preparation of the liquid recording medium.

The following Table 7 shows the preferable ranges of physical properties to be satisfied by the liquid recording medium in order that it can be effectively usable in the present invention. It is to be noted, however, that the recording medium need not necessarily satisfy all these conditions but is only required to satisfy a part of these conditions shown in Table 7 according to the recording characteristics required. Nevertheless the conditions for the specific heat, thermal expansion coefficient and thermal conductivity shown in Table 7 should be met by all the recording medii. Also it is to be understood that the more conditions are met by the recording medium the better the recording is.

Table 7

Property (unit)	*General range*	*Preferred range*	*Most preferred range*
Specific heat (J/°K)	0.1—4.0	0.5—2.5	0.7—2.0
Thermal expansion coefficient ($\times 10^{-3}deg^{-1}$)	0.8—1.8	0.5—1.5	
Viscosity (centipoise; 20°C)	0.3—3.0	1—20	1—10
Thermal conductivity ($\times 10^{-3}$W/cm.deg)	0.1—50	1—10	
Surface tension (dyne/cm)	10—85	10—60	15—50
pH	6—12	8—11	
Resistivity (Ωcm)*	10^{-3}—10^{11}	10^{-2}—10^{9}	

*) Applicable when the droplets are charged at the recording.

While I have shown and described certain present preferred embodiments of the invention it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied within the scope of the following claims.

Claims

1. A liquid jet recording process for recording with liquid droplets comprising the steps of:

projecting a liquid from an orifice communicating with a thermal chamber portion by maintaining the same under pressure thereby forming a stream of said liquid directed toward a surface of a record-receiving member;

applying to the liquid contained in said thermal chamber portion a thermal energy generated according to the electrical input signals by an electrothermal transducer coupled to said thermal chamber portion in such a manner as to transmit thermal energy to the liquid contained in said thermal chamber portion thereby instantaneously forming bubbles in said liquid, and applying a periodical force resulting from periodical state change involving instantaneous volumic change of said bubbles to said liquid stream thereby breaking up said stream into a succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said succession and either deflecting or intercepting said droplets thereby causing selective deposition onto said record-receiving member.

2. A process according to the claim 1 wherein plural electrothermal transducers being serially provided in said thermal chamber portion along the flow path of liquid supplied thereto.

3. A process according to the claim 2 wherein the size of droplet being controlled by selectively activating one of said plural electrothermal transducers in response to the selection signals.

4. A process according to the claim 1 wherein the liquid of an amount corresponding to that

projected being replenished to said thermal chamber portion by volumic contraction of bubbles and/or forced pressure after each projection.

5. A process according to the claim 1 wherein the size of droplets formed and/or number thereof per unit time being controlled by controlling the amount of thermal energy per unit time and/or the pressure of liquid supplied to the thermal chamber portion.

6. A liquid jet recording process for recording with liquid droplets comprising the steps of:

projecting a liquid from plural orifices respectively communicating with thermal chamber portions by maintaining the same under pressure thereby forming plural separate streams of said liquid directed toward a surface of a record-receiving member;

applying to the liquids contained in said thermal chamber portions thermal energies generated according to the electrical input signals by plural electrothermal transducers respectivly coupled to said thermal chamber portions in such a manner as to transmit thermal energies to the liquids respectively contained in said thermal chamber portions thereby instantaneously forming bubbles in said liquids, and applying forces resulting from state change involving instantaneous volumic change of said bubbles to said liquid streams thereby breaking up said streams into plural succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said successions and either deflecting or intercepting said droplets thereby causing selective deposition onto said record-receiving member.

7. A process according to the claim 6 wherein plural electrothermal transducers being serially provided in each of said thermal chamber portions along the flow path of liquid supplied thereto.

8. A process according to the claim 7 wherein, in each of said thermal chamber portions, the size of droplet being controlled by selectively activating one of said plural electrothermal transducers in response to the selection signals.

9. A process according to the claim 6 wherein, in each of said thermal chamber portions, the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles and/or forced pressure after each projection.

10. A process according to the claim 6 wherein the size of droplets formed and/or the number thereof per unit time being controlled by controlling the amount of thermal energy per unit time and/or the pressure liquid supplied to the thermal chamber portions.

11. A liquid jet recording process for recording with liquid droplets comprising the steps of:

applying, each time a droplet is to be projected from an orifice communicating with a thermal chamber portion toward a surface of a record-receiving member, to a liquid contained in said thermal chamber portion a thermal energy generated corresponding to an instantaneous value of electrical input signals by an electrothermal transducer coupled to said thermal chamber portion in such a manner as to transmit the thermal energy to the liquid contained in said thermal chamber portion thereby instantaneously forming bubbles in said liquid, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between said chamber portion and said orifice; and

replenishing the thermal chamber portion with the liquid from a reservoir therefor when said force is instantanteously attenuated after the projection of droplet from said orifice.

12. A process according to the claim 11 wherein plural electrothermal transducers being serially provided in said thermal chamber portion along the flow path of liquid supplied thereto.

13. A process according to the claim 12 wherein the size of droplet being controlled by selectively activating one of said plural electrothermal transducers in response to the selection signals.

14. A process according to the claim 11 wherein the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles after each projection.

15. A process according to the claim 11 wherein the size of droplets formed and/or the number thereof per unit time being controlled by the amount of thermal energy per unit time.

16. A liquid jet recording process for recording with liquid droplets comprising the steps of:

applying, each time droplets are to be projected from at least one of orifices respectively communicating with plural thermal chamber portions toward a surface of a record-receiving member, to a liquid contained in each of said thermal chamber portions a thermal energy generated corresponding to an instantaneous value of electrical input signals by an electrothermal transducer coupled to each of said thermal chamber portions in such a manner as to transmit the thermal energy to the liquid contained in corresponding thermal chamber portion thereby instantaneously forming bubbles in said liquid, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between each of said chamber portion and corresponding orifice; and

replenishing each of thermal chamber portions with the liquid from a reservoir therefor when said force is instantaneously attenuated after the projection of droplet from said orifice.

17. A process according to the claim 16 wherein plural electrothermal transducers being serially provided in each of said thermal chamber portions along the flow path of liquid supplied thereto.

18. A process according to the claim 17 wherein, in each of said thermal chamber portions, the size of droplet being controlled by selectively activating one of said plural electrothermal transducers in response to selection signals.

19. A process according to the claim 16 wherein, in each of said thermal chamber portions, the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles after each projection.

20. A process according to the claim 16 wherein the size of droplets formed and/or the number thereof per unit time being controlled by the amount of thermal energy per unit time.

21. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

a thermal chamber portion communicating with said liquid reservoir through a pipe;

an orifice for projecting said liquid and communicating with said thermal chamber portion;

an electrothermal transducer coupled to said thermal chamber portion in such a manner as to transmit thermal energy to the liquid contained in said thermal chamber portion; and

an electrical means for providing said transducer with electrical input signals for generating thermal energy enough for causing the liquid contained in said thermal chamber portion to instantaneously generate bubbles therein and to undergo a state change involving volumic change of said bubbles, whereby said liquid being projected from said orifice by the force resulting from said state change to achieve recording.

22. An apparatus according to claim 21 wherein said electrothermal transducer comprising a heat-generating resistor, electrodes for supplying current to said resistor, and a protective layer.

23. An apparatus according to the claim 22 wherein said heat-generating resistor being provided on a heat accumulating layer.

24. An apparatus according to the claim 22 wherein said heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

25. An apparatus according to the claim 22 wherein said protective layer having a thickness within a range from 0.01 to 10 microns.

26. An apparatus according to the claim 23 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

27. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

a thermal chamber portion wherein the liquid supplied from said reservoir through a pipe and contained in said portion undergoes instantaneous periodic state changes upon receipt of thermal energy;

an orifice for projecting said liquid and communicating with said thermal chamber portion;

an electrothermal transducer coupled to said thermal chamber portion in such a manner as to transmit thermal energy to the liquid contained in said thermal chamber portion; and

an electrical means for providing said transducer with electrical input signals for generating thermal energy enough for causing said state change, whereby said liquid present in front of said thermal chamber portion being projected from said orifice by the force resulting from said state change to achieve recording.

28. An apparatus according to the claim 27 wherein said electrothermal transducer comprising a heat-generating resistor, electrodes for supplying current to said resistor, and a protective layer.

29. An apparatus according to the claim 28 wherein said heat-generating resistor being provided on a heat accumulating layer.

30. An apparatus according to the claim 28 wherein said heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

31. An apparatus according to the claim 28 wherein said protective layer having a thickness within a range from 0.01 to 10 microns.

32. An apparatus according to the claim 29 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

33. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

a thermal chamber portion wherein a liquid contained therein undergoes a state change upon receipt of thermal energy;

a supply chamber connected to said thermal chamber portion for supplying the liquid from said reservoir to said thermal chamber portion;

an orifice for projecting said liquid and communicating with said thermal chamber portion;

an electrothermal transducer constituting at least a part of internal wall of said thermal chamber portion so as to transmit the generated thermal energy to the liquid contained in said thermal chamber portion; and

an electrical means for providing said transducer with electrical input signals for generating thermal energy enough for causing said state change, whereby said liquid being projected from said orifice by the force resulting from said state change to achieve recording.

34. An apparatus according to the claim 33 wherein said electrothermal transducer comprising a heat-generating resistor, electrodes for supplying current to said resistor, and a protective layer.

35. An apparatus according to the claim 34 wherein said heat-generating resistor being provided on a heat accumulating layer.

36. An apparatus according to the claim 34 wherein said heat generating resistor having a thickness within a range from 0.001 to 5 microns.

37. An apparatus according to the claim 34 wherein said protective layer having a thickness within a range from 0.01 to 10 microns.

38. An apparatus according to the claim 35 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

39. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

plural thermal chamber portions wherein a liquid contained therein undergoes a state change upon receipt of thermal energy;

a supply chamber connected to said thermal chamber portions for supplying the liquid from said reservoir to said thermal chamber portions;

plural orifices for projecting said liquid and respectively communicating with said thermal chamber portions;

plural electrothermal transducers each of which constitutes at least a part of internal wall of each of said thermal chamber portions so as to transmit the generated thermal energy to the liquid contained in each of said thermal chamber portions; and

plural electrical means respectively providing said transducers with independent electrical input signals for generating thermal energy enough for causing said state change, whereby said liquid being projected from each of said orifices by the force resulting from said state change to achieve recording.

40. An apparatus according to the claim 39 wherein each of said electrothermal transducers comprising a heat-generating resistor, a selecting electrode, and an electrode common to said transducers, said selecting electrode being provided along the flow path of the liquid supplied to said thermal chamber portion.

41. An apparatus according to the claim 40 wherein each heat-generating resistor being provided on a heat accumulating layer.

42. An apparatus according to the claim 40 wherein each heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

43. An apparatus according to the claim 41 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

44. An apparatus according to the claim 39 wherein each of said electrothermal transducers comprising a heat-generating resistor, a selecting electrode, an electrode common to said transducers, and a protective layer for preventing shortcircuiting by said liquid between said selecting and common electrodes.

45. An apparatus according to the claim 44 wherein said selecting electrode being provided along the flow path of the liquid supplied to said thermal chamber portion.

46. An apparatus according to the claim 46 wherein each heat-generating resistor being provided on a heat accumulating layer.

47. An apparatus according to the claim 44 wherein each heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

48. An apparatus according to the claim 46 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

49. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

a thermal chamber portion wherein a liquid contained therein undergoes a state change upon receipt of thermal energy;

a supply chamber connected to said thermal chamber portion for supplying the liquid from said reservoir to said thermal chamber portion;

an orifice for projecting said liquid and communicating with said thermal chamber portion;

an electrothermal transducer provided on the external wall of said thermal chamber portion so as to transmit the generated thermal energy to the liquid contained in said thermal chamber portion; and

an electrical means for providing said transducer with electrical input signals for generating thermal energy enough for causing said state change, whereby said liquid being projected from said orifice by the force resulting from said state change to achieve recording.

50. An apparatus according to the claim 49 wherein said electrothermal transducer comprising a heat-generating resistor, electrodes for supplying current to said resistor, and a protective layer.

51. An apparatus according to the claim 50 wherein said heat-generating resistor being provided on a heat accumulating layer.

52. An apparatus according to the claim 50 wherein said heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

53. An apparatus according to the claim 50 wherein said protective layer having a thickness within a range from 0.01 to 10 microns.

54. An apparatus according to the claim 51 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

55. A liquid jet recording apparatus comprising:

a liquid reservoir for storing a liquid;

plural thermal chamber portions wherein a liquid contained therein undergoes a state change upon receipt of thermal energy;

a supply chamber connected to said thermal chamber portions for supplying the liquid from said reservoir to said thermal chamber portions;

plural orifices for projecting said liquid and respectively communicating with said thermal chamber portions;

plural electrothermal transducers respectively provided on external walls of said thermal chamber portions so as to transmit the generated thermal energy to the liquid contained in said thermal chamber portions; and

plural electrical means respectively providing said transducers with independent electrical input signals for generating thermal energy enough for causing said state change, whereby said liquid being projected from each of said orifices by the force resulting from said state change to achieve recording.

56. An apparatus according to the claim 55 wherein each of said electrothermal transducers comprising a heat-generating resistor, a selecting electrode, and an electrode common to said transducers, said selecting electrode being provided along the flow path of the liquid supplied to said thermal chamber portion.

57. An apparatus according to the claim 56 wherein each heat-generating resistor being provided on a heat accumulating layer.

58. An apparatus according to the claim 56 wherein each heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

59. An apparatus according to claim 57 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

60. An apparatus according to the claim 55 wherein each of said electrothermal transducers comprising a heat-generating resistor, a selecting electrode, an electrode common to said transducers, and a protective layer for preventing shortcircuiting by the liquid between said selecting and common electrodes.

61. An apparatus according to the claim 60 wherein each selecting electrode being provided along the flow path of the liquid supplied to said thermal chamber portion.

62. An apparatus according to the claim 60 wherein each heat-generating resistor being provided on a heat accumulating layer.

63. An apparatus according to the claim 60 wherein each heat-generating resistor having a thickness within a range from 0.001 to 5 microns.

64. An apparatus according to the claim 62 wherein said heat accumulating layer having a thickness within a range from 0.01 to 50 microns.

65. A liquid jet recording process for recording with liquid droplets comprising the steps of:

projecting a liquid from an orifice communicating with a thermal chamber portion by maintaining the same under pressure thereby forming a stream of said liquid directed toward a surface of a record-receiving member;

applying to the liquid contained in said thermal chamber portion a thermal energy generated according to the optical input signals by a photothermal transducer coupled to said thermal chamber portion in such a manner as to transmit thermal energy to the liquid contained in said thermal chamber portion thereby instantaneously forming bubbles in said liquid, and applying a periodical force resulting from periodical state change involving instantaneous volumic change of said bubbles to said liquid stream thereby breaking up said stream into a succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said succession and either deflecting or interception said droplets thereby causing selective deposition onto said record-receiving member.

66. A process according to the claim 65 wherein the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles and/or forced pressure after each projection.

67. A process according to the claim 65 wherein the size of droplets formed and/or the number thereof per unit time being controlled by controlling the amount of thermal energy per unit time and/or the pressure of liquid supplied to the thermal chamber portion.

68. A liquid jet recording process for recording with liquid droplets comprising the steps of:

applying, each time a droplet is to be projected from an orifice communicating with a thermal chamber portion toward a surface of a record-receiving member, to a liquid contained in said thermal chamber portion a thermal energy generated corresponding to an instantaneous value of optical input signals by a photothermal transducer coupled to said thermal chamber portion in such a manner as to transmit the thermal energy to the liquid contained in said thermal chamber portion thereby

instantaneously forming bubbles in said liquid, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between said chamber portion and said orifice; and

replenishing the thermal chamber portion with the liquid from a reservoir therefor when said force is instantaneously attenuated after the projection of droplet from said orifice.

69. A process according to the claim 68 wherein the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles after each projection.

70. A process according to the claim 68 wherein the size of droplets formed and/or the number thereof per unit time being controlled by the amount of thermal energy per unit time.

71. A liquid jet recording process for recording with liquid droplets comprising the steps of:

projecting a liquid from an orifice communicating with a thermal chamber portion by maintaining the same under pressure thereby forming a stream of said liquid directed toward a surface of a record-receiving member;

irradiating the liquid contained in said thermal chamber portion with a laser light to cause said liquid to absorb the energy of said laser light and to generate heat thereby instantaneously forming bubbles in said liquid, and thus applying a periodical force resulting from periodical state change involving instantaneous volumic change of said bubbles to said liquid stream thereby breaking up said stream into a succession of evenly spaced uniform separate droplets; and

selectively charging electrically the droplets in said succession and either deflecting or interception said droplets thereby causing selective deposition onto said record-receiving member.

72. A process according to the claim 71 wherein the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles and/or forced pressure after each projection.

73. A process according to the claim 71 wherein the size of droplets formed and/or the number thereof per unit time being controlled by controlling the amount of thermal energy per unit time and/or the pressure of liquid supplied to the thermal chamber portion.

74. A liquid jet recording process for recording with liquid droplets comprising the steps of:

applying, each time a droplet is to be projected from an orifice communicating with a thermal chamber portion toward a surface of a record-receiving member, the energy of a laser to a liquid contained in said thermal chamber portion thereby generating heat in said liquid and instantaneously forming bubbles therein, and thus applying a force, resulting from a state change involving instantaneous volumic change of said bubbles and enough for causing the liquid droplet to be projected from the orifice against the surface tension of said liquid at said orifice, to the liquid present between said chamber portion and said orifice; and

replenishing the thermal chamber portion with the liquid from a reservoir therefor when said force is instantaneously attenuated after the projection of droplet from said orifice.

75. A process according to the claim 74 wherein the liquid of an amount corresponding to that projected being replenished to said thermal chamber portion by volumic contraction of bubbles after each projection.

76. A process according to the claim 74 wherein the size of droplets formed and/or the number thereof per unit time being controlled by the amount of thermal energy per unit time.

77. Liquid jet recording process substantially as herein described with reference to the accompanying drawings.

78. Liquid recording apparatus substantially as herein described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1979. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.